Industrial Development Subsidiary Agreement

REVIEW OF SPECIES AVAILABLE FOR MARICULTURE IN BRITISH COLUMBIA

FEBRUARY 1983

Research Report

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REVIEW OF SPECIES AVAILABLE FOR MARICULTURE IN BRITISH COLUMBIA

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REVIEW OF SPECIES AVAILABLE FOR MARICULTURE IN BRITISH COLUMBIA

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The responsibility for the report, as written, and all conclusions reached herein, are the consultants' alone, and the report does not necessarily reflect the opinions of those who assisted during the course of this investigation or the Federal and Provincial governments, which funded the study. The opinions expressed in the report are not necessarily those held personally by the authors, who made a conscious attempt to present consensual opinions as far as possible.

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EXECUTIVE SUMMARY

Purpose of Study

The major purpose of this study is to review the present status of the mariculture industry in British columbia. The scope of the study includes the industry view of required research in biological, engineering and technological, and marketing areas. While a ranking of mariculture species by their potential has not been made explicitly, the reader will be able to see the factors limiting future development of some species. The research requirements, which have been defined by industry, should contribute toward helping those agencies funding mariculture research and development to determine the needs and priorities of mariculturalists.

Study Method

The 1982 Review of Species Available for Mariculture in British Columbia is the result of an initial series of workshops which were attended by representatives of both industry and government. These workshops were designed to allow participants to both give and analyse information and to allow an exchange of ideas on problems and potentials.

Following the presentation of the workshop minutes, an additional contract was let to combine all of the species covered in a written review. The contract funding was intended to cover reporting on the workshop proceedings. The authors felt, however, that extensive interviews, literature reviews, and analyses of available information were necessary to fill the knowledge gaps exposed by the workshops and produce an acceptable written review. While realizing that this extensive work was beyond the scope of the terms of reference, the authors attempted to partially satisfy the desired quality objectives by sending early drafts of the reviews to selected participants for comment and editing, and by donating some of their own time and effort in additional literature reviews, analyses, and re-writing of drafts. Although the product could well benefit from additional

new work, it hopefully contributes significantly to understanding of the current status of mariculture species in British columbia.

Findings and Observations

Our major findings and observations with regard to species suitable for mariculture in British Columbia are as follows:

1. British Columbia has considerable potential to produce salmon, oysters and probably clams and scallops by mariculture techniques. There is insufficient knowledge about abalone and marine plants to evaluate their potential. Mussels appear, at the time of writing, to have fundamental biological problems. Shrimp, prawns, crab and lobster have no significant mariculture potential in the next five years at least.

2. Two major problems apply to all of the resources considered: profitability of production, and markets and promotion. With the exception of a few oyster farmers, profits have been slow coming to mariculturalists. Insufficient market development, research, and promotion are common problems for all the species which have so far produced marketable products.

3. Although jurisdictional and legal problems exist for some species and have caused problems to some growers, generally speaking, these problems are not at present seriously inhibiting the development of mariculture in British Columbia.

4. Continued government encouragement, and patience, will be required before the potential of even the more promising species can be realized in industrial operations.

5. Much recent research funding directed toward mariculture has been ad-hoc and outside any clear policy framework. On many occasions, disappointing results have been achieved. This does not necessarily indicate that all mariculture efforts are doomed to failure.

Findings and Observations (Cont'd.):

6. The financial requirements of mariculture businesses vary from species to species, but are generally higher than is commonly supposed. The long lag times before cash flow, and the extensive and intensive demands on the skills of the entrepreneur, make mariculture a difficult business enterprise.

Conclusions and Recommendations

Based on the research undertaken, our conclusions regarding the mariculture species are as follows:

1. OYSTERS - Costs of production need to be reduced and seed sources improved.
It still remains the shellfish with the highest overall potential for culture.

2. SCALLOPS - Research and development is required on seed acquisition and the economics of grow-out.
The overall potential appears favourable for some species.

3. CLAMS - At present prices and costs, the prospects of clam culture are dubious; thus work contributing to the reduction of production costs should be of high priority.

4. MUSSELS - The problem of summer die-off over a wide variety of culture sites has led to doubts about the ability of B.C. waters to sustain mussel culture operations.

Conclusions and Recommendations (Cont'd.)

- Based upon limited market and price data, there are questions as to the relative priority of continued research into the summer mortality problem, especially as considerable market uncertainties exist.

5. ABALONE - Research presently being undertaken on labour inputs, economic viability, growth rates, and culture methods, should go some way toward answering questions about abalone farming. Insufficient information is available to draw any conclusions as to viability.

6. SALMON - Pen salmon have considerable potential for culture. Many problem areas exist where research is needed, especially in technology and marketing. Some firms are on the threshold of profitability and markets appear to be good.

7. MARINE PLANTS - The potential for the culture of marine plants for food is unclear at present. It appears additional research is justified in the area of agar production.

8. SHRIMP, PRAWNS, LOBSTER AND CRAB - A variety of problems make these species unlikely candidates for culture at this time.

9. GOOSENECK BARNACLES - Insufficient information is available to evaluate the potential for culture.

OYSTERS

OYSTERS

Introduction

The Pacific Oyster (Crassostrea gigas Thunberg) forms the foundation of invertebrate mariculture in British Columbia. Techniques and markets are generally well established, although abundant room for improvement exists; the most significant inhibitors to expansion are economic.

History

The history of oyster culture in British Columbia has been well documented by Quayle (1969) and others. The industry is now emphasizing farming as opposed to crown foreshore wild harvest, with planned collection and planting of seed. Culture methods presently employed are of four different types: bottom, near-bottom, off-bottom and tray for two product lines: fresh shucked oysters and single oysters in the shell (often referred to as "half shell" oysters)

Production has declined steadily since the mid 1970's (See Appendix I), while growing and seed collection techniques have improved. While B.C. production is presently confined to southern waters, Quayle (1971) and others have shown that satisfactory, although slower, growth rates can be achieved in areas north of Johnstone Strait. Vast areas of clean, rich water are available for off-bottom oyster culture. Highly productive bottom land is at a premium, although most of what is presently leased is not being used at full capacity. This unrealized production potential results from financing difficulties and from past poor management on the part of lease holders. Appendix I contains production volume information for B.C. oyster production since 1965.

Licensing and Jurisdictional

No inhibitors to oyster industry growth or prosperity exist because of oyster-specific government policies, although this statement may be at odds with the experiences of beginners fighting for a lease or established growers arguing tax assessments. The oyster industry is under Provincial control but with some Federal Department of Fisheries and Oceans (D.F.O.) input. The day-to-day administration has been in the hands of the British Columbia government since 1912 and is presently vested in the Marine Resources Branch (M.R.B.) of the B.C. Ministry of Environment, but D.F.O. are involved in health aspects (plant inspection and product regulations) and research. From the growers' point of view, this system is generally working at the production end of the industry, but overlapping Federal and Provincial responsibilities in processing and distribution requirements are proving troublesome. These regulations detailing the packaging and selling of shucked oysters are causing much concern with the industry as the requirements and interpretation of various departments and branches are different. For example, "best before dates" are required by D.F.O. but are not enforced by Federal Consumer Affairs; contents labeling and standards are inconsistent between the latter and Fisheries Regulations and the Provincial Fish Inspection Act. These areas are being worked on by the B.C. Oyster Growers Assoc. (B.C.O.G.A.) but it is a time-consuming process.

The British Columbia oyster industry has long felt the need for longer term leases, with more security of tenure and less restrictive application of the riparian right of access. Good progress seems to be being made in these areas by the Ministry of Lands, Parks and Housing and M.R.B.

Problems associated with Paralytic Shellfish Poison (P.S.P.) monitoring and the system of closures are of considerable concern to the oyster industry. The health consequences are clearly recognized and processors are proud of their accident free record; however, there is some feeling

within the industry that widespread, well publicized closures are sometimes imposed based upon insufficient evidence.

D.F.O. base closure decisions on the "toxin level found in mussels and other bivalve mo lluscs. Historic data are also taken into consideration" (Wilson pers. comm.).

It appears obvious that the oyster industry stands to benefit greatly from the strong advocacy position taken by M.R.B. on behalf of mariculture. Two recent policy initiatives have been greeted with mixed enthusiasm by the industry. These are the mariculture reserve work, generally regarded as proceeding too slowly and long overdue, and the diligent use policy, welcomed by some, but seen as a threat by others.

Biological/Technological Research and Future Needs

A. Present biological work being carried out:

1. Seed Procurement: Genetic and hydrographic studies are being carried out in Pendrell Sound to investigate causes for this area's apparent decrease in productivity.

   Innovative Aquaculture Products Ltd. have recently prepared a manual (Jones and Jones 1982) on eyed oyster larval setting, and coordinated two field studies of this technique in remote locations in 1982.

2. Area Evaluation: M.R.B. are conducting a growth study using several culture methods in the Ladysmith Harbour to determine the area's present productivity. (The "Smoked and Canned Study" is also generating a great deal of data on off-bottom culture growth rates by area and on condition indexes).

3. Depuration research being conducted by the Fish Technology Laboratory (D.F.O.) has also yielded valuable condition index information and may lead to some possibilities of chemically assisted shucking.

B. The oyster industry has identified the following areas of biological research needs:

1. Seed Procurement: More work is required in Pendrell Sound, probably using a coordinated "team" approach, to determine the extent of productivity loss, genetic problems (if any), plankton distribution and hydrography. As long as Pendrell Sound remains the most important source of oyster seed, every effort must be made to protect this valuable resource and, for this reason, Pendrell research deserves high priority. Ultimately, hatchery produced seed may well replace Pendrell, but this is unlikely to happen for some time.

   Tray growers are still looking for a simple, cheap source of single oysters.

   Eyed larval setting will continue to require research effort, especially for successful setting on artificial substrates.

2. Growth: There is still a need for depth optimization studies to provide off and near-bottom growers with more information on likely high productivity, and low fouling regions (see below) in their leases. It is acknowledged that this work is likely to be site specific to some extent.

3. Fouling: The effects and prevention of fouling continues to be a cause of concern to off-bottom growers. There is a need for systematic work to quantify the problem, and a need for a "fouling handbook" that would explain to growers the likely effects of different fouling types, and suggest preventatives or solutions where growth is found to be adversely affected.

C. Engineering and material handling work currently underway in British Columbia:

1. Bottom Culture: There does not seem to be a great deal of research taking place in this area. Innovations in harvesting and handling are gradually occurring as larger growers face labour rate and other cost increases. Shell cultch, now packed exclusively in bags (mostly "Vexar"), is still the norm, although "French Hats" and "Diamond Chips" are also used on beaches by some growers. Most harvest is by hand, as is all shucking.

2. Near-Bottom Culture: The M.R.B. work of 1978 - 1980 has led to a renewal of interest in near-bottom culture. Fanny Bay Oyster Co. is using near-bottom long lines, suspended between plastic stakes, with small pieces of shell (often cut) or "chips" as cultch. This technique looks promising for beaches subject to severe winter wave action. Clam Bay Shellfish Co. placed a large number of "umbrella" culture units in 1980/81, but the results were not sufficiently encouraging for them to proceed (Charlie pers. comm.).

3. Off-Bottom Culture: Off-bottom culture is now largely confined to long lines: the early efforts with log rafts for string culture were not successful due to incorrect calculations of the flotation provided by logs. Long lines are also favoured for their lower capital cost and ease of working given present harvest systems, although floats and harvesting methods are still being experimented with.

   No ideal compromise between cost, size, and handling convenience has been found. Presently styrofoam blocks and plastic barrels, either especially made or recycled, are the two most popular and successful floatation methods.

   The "Smoked and Canned" oyster feasibility study, funded by M.R.B. and A.R.D.S.A., to assess the economics of growing string oysters for smoking or breading or an individually quick frozen (I.Q.F.) product, has led to work on flotation stringing, harvesting and the shucking of long line grown oysters. In this project, seven growers are culturing oysters in Southern British Columbia, some of which will be steam shucked.

4. Tray Growing: There is a trend toward beach or inter-tidal tray culture with only final finishing occurring on submerged trays. Half shell growing on trays has not fulfilled its early promise due to the ability of cheaper beach, or perhaps string oysters to substitute for tray grown in many markets.

5. Artificial Cultch: The work being carried out by Aqua Foods Ltd. is aimed at finding a cultch suitable for grow-out by off-bottom or near-bottom techniques without post spatfall spacing, and using a minimum of labour. This work began in May 1981 and preliminary assessments suggest that uncoated plastic tubes look the most promising. Funding was provided by M.R.B.

D. Oyster industry representatives have suggested the following research needs:

1. Shellstock handling: Both beach and off-bottom growers see the need to streamline shellstock handling. While there are certainly lessons to be learned from both Washington and Japan applicable to these two culture methods, the solutions arrived at will have to be adapted to our conditions, such as generally smaller leases and less suitable bottom ground for dredge harvest. Off-bottom oysters would be more attractive to processing by hand, if they were washed and declustered.

2. Processing: Without regular and steady oyster price increases, it is doubtful that all B.C. production can continue to be hand shucked much longer. The wage and benefit package and working conditions being offered to shuckers is not attractive enough to encourage new entrants and the average age of B.C. shuckers is certainly increasing.

   The answer to this is a form of "automatic" shucking, ideally a system which would still result in a fresh product. This dream has been chased by researchers

in many countries; it is reported that 184 patents exist in the U.S.A. alone (National Fisherman 1982), and yet none of these seems to have worked sufficiently well to gain widespread adoption by industry. The work of B.C. Research and Fish Technology Lab. in steam and chemically assisted shucking, respectively, is in need of industry assessment in a commercial plant situation. Eastern U.S. steam assisted shucking methods need assessment in B.C. This should be coupled with an assessment of the Franken B.V. meat shell separation system.

3. Product development: New products are being developed, although not necessarily in response to market demands. New product work includes:

   - smoked and canned product
   - breaded I.Q.F. products
   - frozen prepared half shell products (Oysters Rockefeller, etc. being undertaken by B.C. Research).

   The size of the market for some of these products can be assessed from recent import figures (see Appendix IV).

   Oyster puffs, breaded hors d'oeuvres, soups, sausages or pickles are not presently being produced in B.C., although some of these have been in the past. Market demand potential for these and new products has not been assessed.

   In addition to the obvious economic and market analysis needed in new product development, there is a requirement to develop health and packaging standards, and standards of consistency, if more than one producer is involved.

There is also an urgent need for improved containers which meet regulations, display the product, are tamper proof and are acceptable in price. A recent survey of wholesalers in Vancouver revealed that packaging was a major deficiency of B.C. oyster products compared to Washington State products, which otherwise did not offer price or quality advantages in general (Cahill, 1982).

Markets and Marketing Research Requirements

The economic potential of oyster culture in B.C. has been widely recognized, but never realized. All current estimates of market demand for B.C. oysters show levels exceeding B.C. production by considerable margins. The most conservative estimates (Fralick, M.R.B. pers. comm.) are that demand is roughly twice as large as supply. A very recent and better substantiated estimate (Cahill 1982), supports a potential market demand of up to 1,000,000 gallons of B.C. oysters, which is twenty times current B.C. production, given appropriate marketing promotion. Part of the basis for these estimates is the current level of imports to Canada (200,000 gal. fresh/frozen plus 265,000 gal. canned in 1980; see Appendix IV) and the current Canadian production (about 60,000 gal. from B.C. and 40,000 gal. from Eastern Canada; see Appendix I). Thus, present oyster sales in Canada equal 565,000 gal. yearly. Eastern Canadian and U.S. oyster production are not expected to increase because of increasing environmental problems. In a considerably undersupplied market situation Canadian per capita oyster consumption is only 0.085 kg/yr., thought to be limited by lack of supply; U.S. per capita consumption in 1978 was 0.180 kg/yr., and that level is considerably lower than a number of previous U.S. levels.

Marketing activity in B.C. is minimal and research presently being undertaken is ad hoc and sporadic. Individual oyster growers have conducted enquiries with wholesalers and others regarding U.S. fresh imports and new products, but available information is fragmentary and not analyzed.

There is a clear understanding that the industry must develop new markets for the new production coming on stream from off-bottom string culture and other new operations. It is felt that work is urgently needed to define and detail existing markets - who, where, how much, and to identify new markets and new products. The "Smoked and Canned Study" will also contribute toward market knowledge for value added products. In addition, serious consideration is being given to new distribution methods. This push is coming from growers unhappy with the service being offered by Vancouver wholesalers, but who are also well aware of the difficulties and pitfalls of past cooperative endeavours within the industry. Techniques such as pooling, joint distribution to new distant markets and new product sales/distribution organizations are being discussed. These needs apply to both shucked and half-shell oyster production.

The position of the oyster industry to determine its own pricing policy could be expected to lead to orderly prices, steady price increases and adequate profit levels. The history of the recent past does not bear this out. In hindsight, the reluctance to increase prices sufficiently in the 1970's to keep pace with inflation severely retarded the industry's ability to remain competitive with U.S. growers and maintain investment levels, especially in seeding (Fralick 1979). As a result, by the early 1980's, the industry was weak and profits and production were low at the very time that U.S. competition was severe.

A 10% price decrease in the minimum Oyster Marketing Board price to meet the U.S. challenge does not seem to have resulted in significant sales

increases in the immediate term. At the time of writing, it is difficult to assess the full situation but it does suggest that price cuts, without accompanying promotion, is not a good marketing technique, and can be economically damaging.

In response to pressure from the Department of Fisheries and Oceans, the industry is currently developing grading standards and a year's trial of these grades will take place on a voluntary basis. The formal implementation into fishery regulations of any standard arrived at will probably take some time.

Economic/Financial

Studies have been undertaken on the economics of oyster growing in B.C. (Bissell 1972, Fralick 1979, and Aegis Consulting 1980). These studies have generally shown that, with good management, it is possible to grow oysters profitably, while Aegis Consulting found it feasible that local production could compete with smoked and canned imports. When considering the economics of oyster culture, size, location and growing methods are the important variables.

No information is available on the profit performance of oyster farms, although it has been suggested that, for some firms, fishing income (herring, clams, etc.) are the profit centres, while oysters only break even (Tarnowski pers. comm.). Small hobby farms, with productive, well located and managed leases, are achieving a good return on time invested. Other farmers are putting in very long hours for little return. The largest tray "half shell" grower has been reducing the amount of time oysters spend in the trays suspended from long lines in an attempt to reduce iabour inputs (Gibbons pers. comm.). Off-bottom oyster culture has so far not proven profitable, although the special circumstances of two of the pioneering firms do not

allow firm conclusions to be drawn. Records being kept by participants in the "Smoked and Canned Study" (see below) will provide some cost and yield data for off-bottom production.

Appendix II provides wholesale price data for both Washington State and British Columbia since 1965. Appendix III provides tentative estimates of B.C. production costs by culture method.

Summary of Conclusions and Recommendations

Oyster production in British Columbia has followed a declining trend in spite of significant progress in culture technology and seed procurement methods. This lack of development may be in part related to poor profit margins at present costs of production and price levels, although little information is available on the economics of oyster farms at any scale. This would indicate that:

(1) cost information should be generated, and
(2) methods to reduce costs of production should receive high priority.

Seed sources, including Pendrell Sound natural set and hatchery/setting tank production, are vital to the industry and should continue to receive high priority status. Fouling and growth maximization work would contribute to reducing production costs. Other needs are to improve shellstock handling methods, automated or automatically assisted shucking, market development for new products, and improvements in packaging quality and packaging quality uniformity. Marketing promotion work is needed for all oyster products.

Based on the long experience with and knowledge of oyster culture in B.C., the presence of an established industry, and the apparently high market potential, oysters remain the shellfish with the highest overall potential for culture in B.C.

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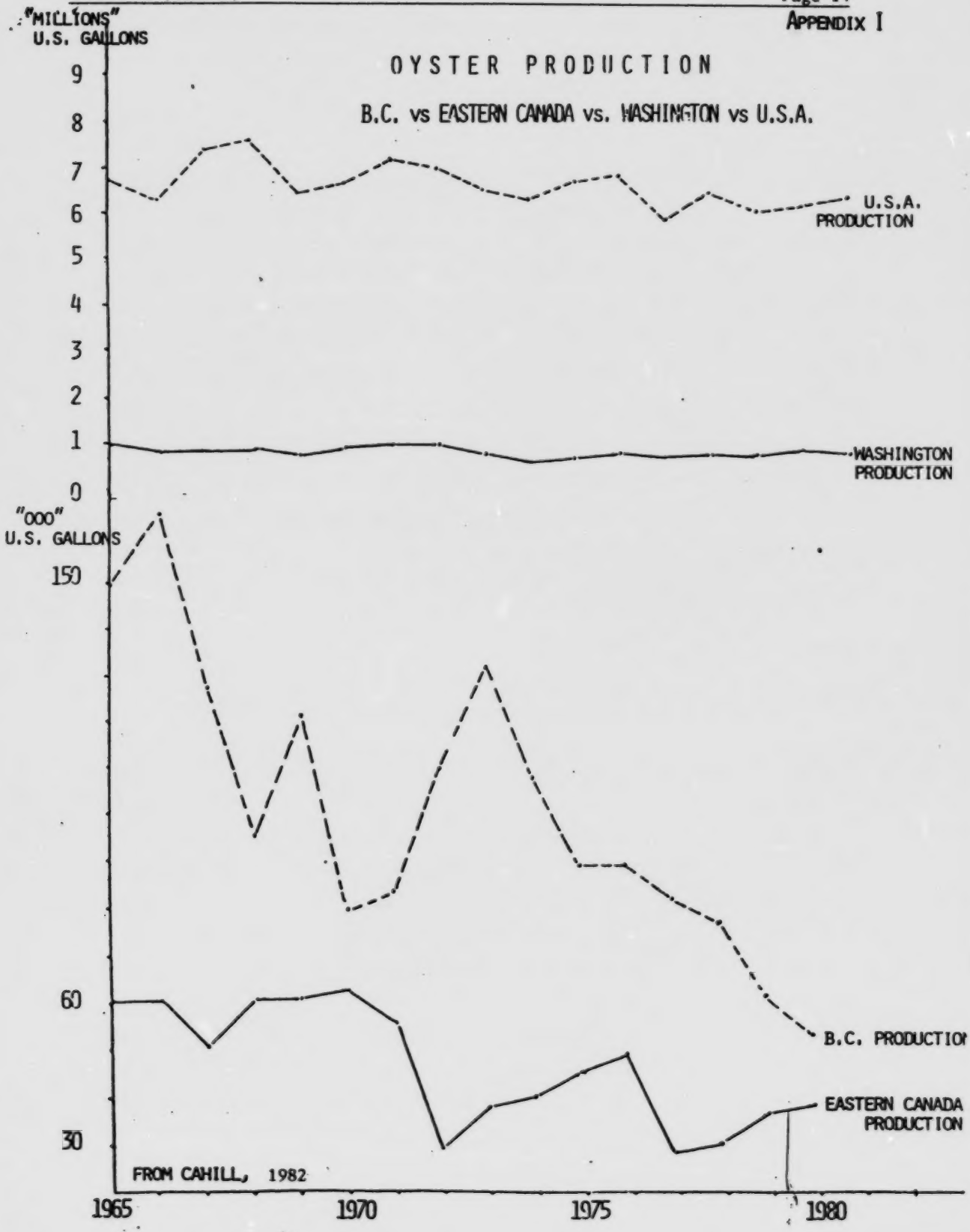
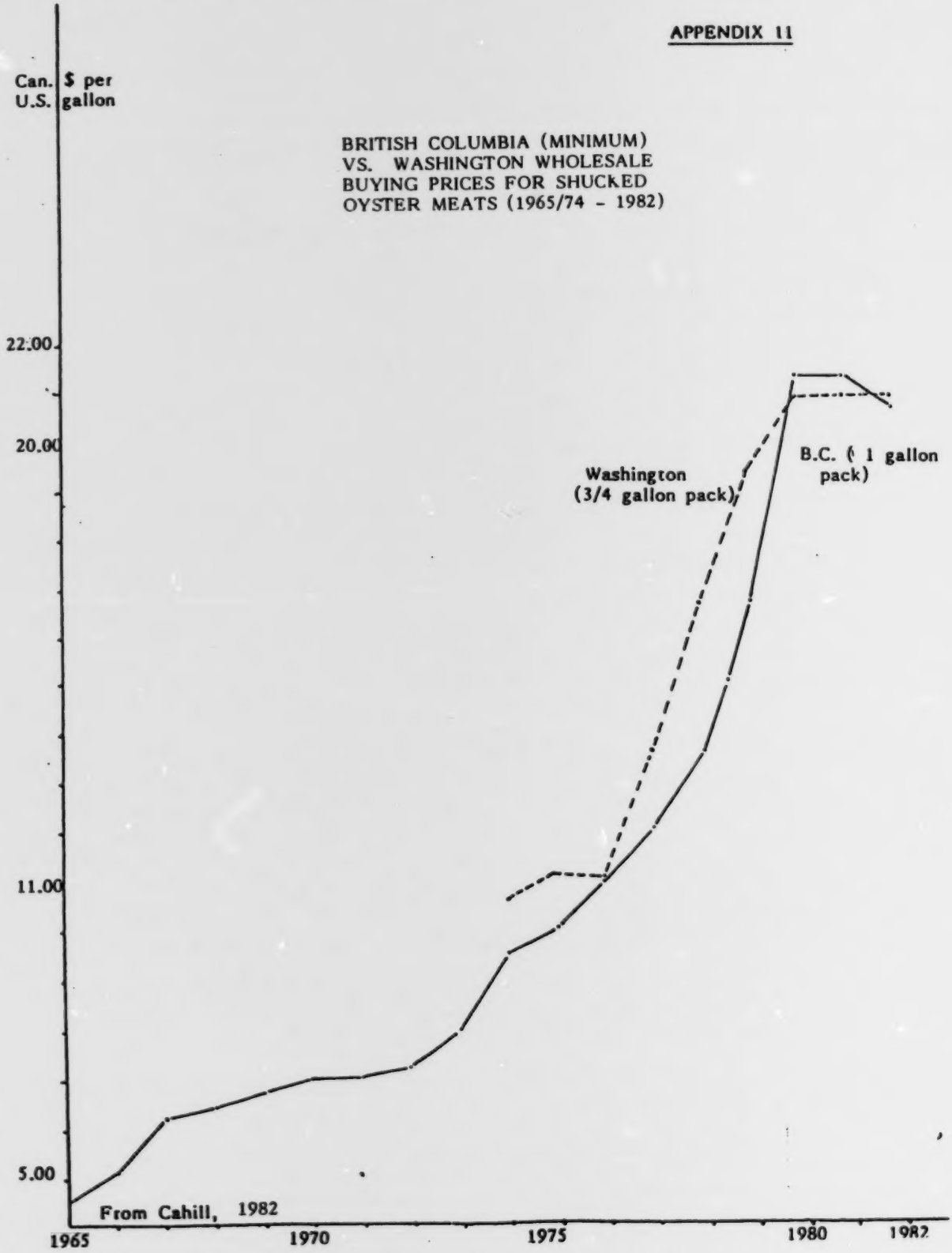
APPENDIX I


"MILLIONS" U.S. GALLONS
OYSTER PRODUCTION
B.C. vs EASTERN CANADA vs. WASHINGTON vs U.S.A.
9
8
7
6
5
4
3
2
1
0
U.S.A. PRODUCTION
WASHINGTON PRODUCTION
"000" U.S. GALLONS
150
60
30
B.C. PRODUCTION
EASTERN CANADA PRODUCTION
FROM CAHILL, 1982
1965
1970
1975
1980

APPENDIX 11


Can. $ per
U.S. gallon
BRITISH COLUMBIA (MINIMUM)
VS. WASHINGTON WHOLESALE
BUYING PRICES FOR SHUCKED
OYSTER MEATS (1965/74 - 1982)
22.00
20.00
11.00
5.00
Washington
(3/4 gallon pack)
B.C. (1 gallon
pack)
From Cahill, 1982
1965
1970
1975
1980
1982

APPENDIX III

Costs of Growing and Processing Oysters in British Columbia, per U.S. gallon, as estimated by Workshop Participants

Cost Item	Growing Method		
	Stake	Bottom	String
Seed requirements(1)	$ 1.20	$ 1.70	$ 1.00
Floats, stakes, rope, etc.	0.80	-	0.90
Labour (at $6.00/per hr.)			
- to place seed	0.65	0.25	0.45
- to maintain	0.30	0.15	0.35
- to harvest	0.75	1.00	1.10
Overhead of growing (2) (boats, lease, office, etc.)	0.55	0.55	0.60
Shucking wages (at $4.00 per gallon)	4.32	4.32	4.60
Grading wages (at $6.00 per hour)	2.16	2.16	2.16
Packing and freight (4)	2.40	2.40	2.40
Plant overheads (2)	1.50	1.50	1.50
B.C. Oyster Marketing Board	0.30	0.30	0.30
Total	$ 14.93	$ 14.33	$ 15.36

NOTES:

(1) Seed costs are much lower for large growers who collect their own seed. Costs based on $8.00 per bag of 100 shells.

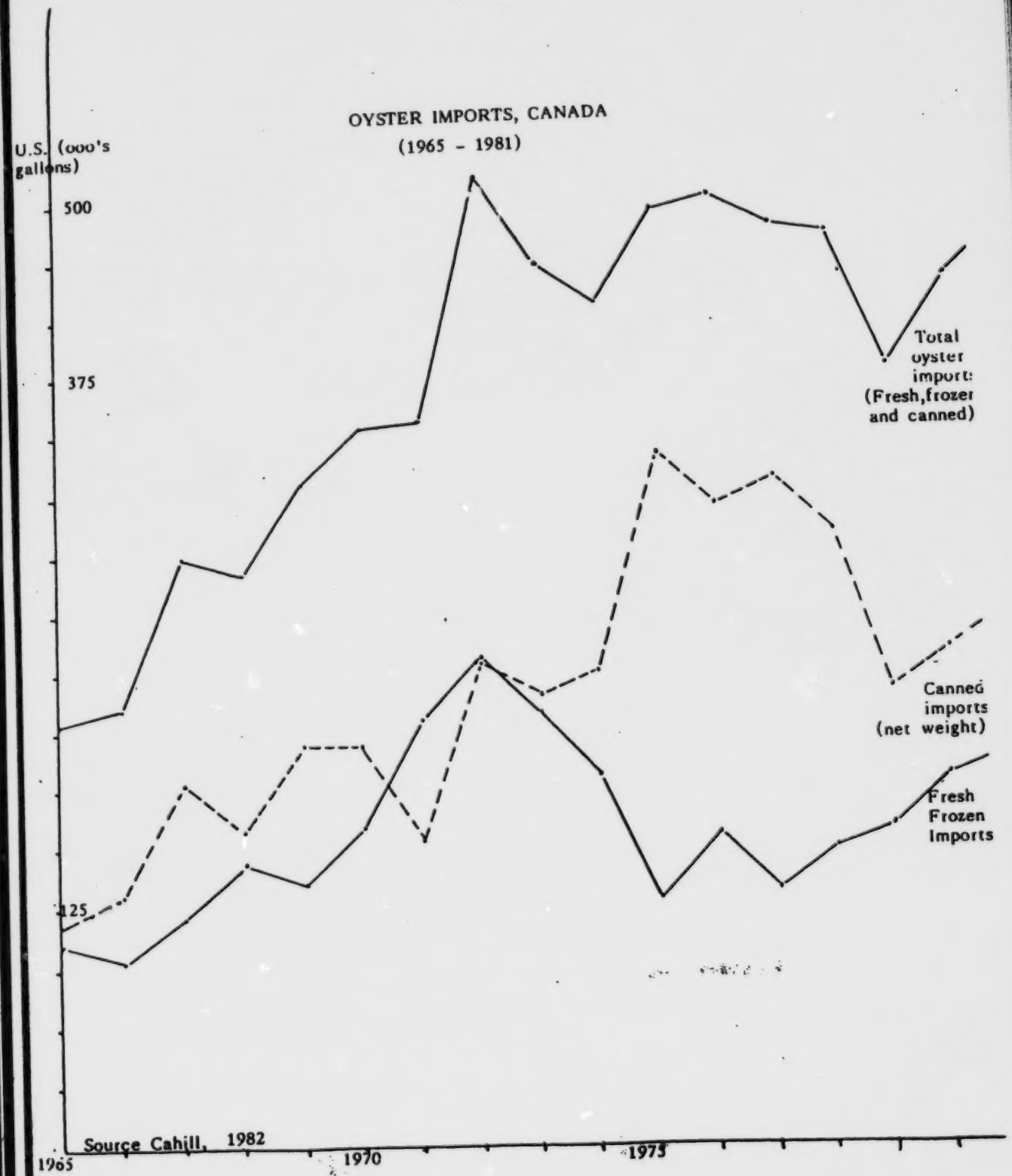
(2) These costs are highly variable, depending on scale of production and location.

(3) Allowance has been made for washing and cluster breaking of the string and stake grown oysters.

(4) Based on Union Bay/Fanny Bay location for processing plant.

(5) No allowance has been made for interest costs on capital and working capital.

(6) Selling prices as of October, 1982 are:
- Shellstock sold for shucking - $7.50 to $8.50 per gallon at shucking plant.
- Custom shucked oysters for packing - $16.00 to $19.00 per gallon.
- B.C. Oyster Marketing Board minimum price in 32 oz. containers - wholesale $19.40 per gallon, retail $23.28 per gallon.


OYSTER IMPORTS, CANADA
(1965 - 1981)
U.S. (000's gallons)
500
375
125
Total oyster import: (Fresh, frozer and canned)
Canned imports (net weight)
Fresh Frozen Imports
1965
1970
1975
Source Cahill, 1982

SCALLOPS

SCALLOPS

Introduction

Scallops are not presently cultured in British Columbia except experimentally. Occasional minor fisheries for pink and weathervane scallops occur and have marketing success, but are limited by low stocks in B.C. Considerable quantities are imported to B.C. as frozen shucked adductor muscles.

Biological/Technological Research and Future Needs

Culture methods for the weathervane scallop, Patinopecten caurinus, could be adapted from Japanese methods used for Patinopecten yessoensis (cf. Aomori Prefecture 1975, Sanders 1973). Potential problems for experimental investigation would relate to the local species' environmental tolerances and optima. Preliminary tests with earhanging and lantern basket culture methods showed good survival. For the rock scallop, Hinnites multirugosus, and for the pink and spiny scallops, Chlamys rubida and C. hericia, survival and growth rates in pearl net and lantern basket cultures are excellent (Valiela 1982). These growth rates, covering the period between September and April and a number of different size classes, would extrapolate to growth periods of two years or at least three growing seasons, to attain adductor muscles of marketable size for either the rock or the pink and spiny scallop. If these species were marketed whole (in the shell), a shorter period in culture would probably be sufficient. At least at small volumes, pinks are successfully being sold whole by the existing fishery near Victoria (R. Strong pers. comm.). Although reservations are often expressed about use of the whole scallop versus the adductor only, due to the relatively low levels of Paralytic Shellfish Poison (P.S.P.) contamination of muscle tissue in bivalves, there are monitoring mechanisms that would aid in safe use of whole scallops. The oysters, mussels, and clams currently being marketed all carry similar P.S.P. risks, which are reduced by the product monitoring and P.S.P. closure systems in place.

Prospects for culturing imported species are uncertain. In addition to problems of environmental differences, especially with the Japanese scallop Patinopecten yessoensis, importation of a foreign species should be considered conservatively. Since there are numerous native scallop species, several of which are of commercial interest, these should be investigated first. They are likely to be easier to culture in B.C. than foreign species, and unexpected negative effects of introductions would not be risked.

Sources of seed for scallop culture need to be developed. Attempts to obtain weathervane scallop seed have been unsuccessful to date (see below); for this species, the only viable method in B.C. may be hatchery production. For rock, spiny, and pink scallop, a considerable quantity (more than 5,000 individuals) of seed has been collected with relatively little effort, from populations in Desolation Sound and Lasqueti Island (Valiela 1982). There is a high priority need to study the distribution and reproductive ecology of rock, pink and spiny scallop populations to evaluate the potential of commercial seed collection from natural populations of these three species, as well as the potential for hatchery production of seed for these species as well as for weathervane scallops. Methods developed elsewhere should be adaptable here, at least for weathervanes (cf. Sanders 1973, Aomori Prefecture 1975) and rock scallops (cf. Leighton and Phleger 1981).

Highest priority research for development of a scallop culture industry is development of seed sources. Possible promising sources are hatchery production for weathervane, rock, spiny and pink scallops, and natural set collection for rock, spiny, and pink scallops. Grow-out and economics of grow-out require research.

Research in Progress

Pacific Biological Station Scallop Research

A project is underway at the Pacific Biological Station in Nanaimo, B.C., to investigate the feasibility of scallop culture in British Columbia; four native species are under study - weathervane, rock, pink, and spiny.

Major emphasis of the study is on weathervale scallops since they are thought by Neil Bourne of P.B.S. to have the most potential for a commercially viable culture operation; they are large and attain a harvestable size (120 mm shell height) in 3-4 years. Rock scallops are also large and studies in California indicate they have potential for culture. Pink and spiny scallops are small, maximum size 85 mm shell height at which they are in 4-5 years, but they may have some potential for culture.

The initial problem in establishing a culture operation with any species is to assure a plentiful, reliable and inexpensive supply of seed (juveniles). Major emphasis of the current project is to devise methods to achieve this end.

The feasibility of culturing two exotic scallop species is also being investigated; sea scallops, Placopecten magellanicus, from the Atlantic coast, and the Japanese scallop, Pacinopecten yessoensis. Brood stock will be brought in under quarantine conditions, and only the offspring planted in the open environment to prevent any introduction of pests, parasites and diseases.

The project is only in the initial stages and no concrete results are available. Funding is by Marine Resources Branch and Department of Fisheries and Oceans.

U.B.C. Research on Scallop Culture

A project funded by Science Council of B.C. is being conducted at University of British Columbia by J. Zahradnik and D. Valiela. Rock, pink and spiny scallops are in pearl and lantern net systems at Lasqueti Island, Trevenen Bay, Refuge Cove, and Waddington Channel. Survival, growth rates, and environmental parameters are being monitored at each site monthly. Culture systems are at three different depths. Seed has been and is being collected at a number of different sites using oyster shell in Vexar bags; as well as seed acquisition, information on timing of set is being collected. Some pilot culture trials with weathervane scallops are also in place in the Gulf Islands. Completion of the final report is expected in early 1983; funding termination in October, 1982.

Markets/Marketing Research Requirements

Demand and markets for scallop products appear to be quite favourable (see Appendices I, II and III), although existing estimates of profit margins and quantities demanded are rough approximations. The Victoria fishery for pink scallops and the Gulf Islands fishery for weathervane have experienced marketing success at high selling prices (although low volumes were involved). Some work in marketing of scallops (e.g., rock scallops, smaller-size whole scallops of any species, quantity demanded at various price levels, etc.) would be helpful to further evaluate market potential, but is not of highest priority, as market prospects appear quite favourable at present.

Conclusions and Recommendations

The overall potential for development of scallop culture in B.C. appears to be favourable. Market acceptability and demand are excellent, culture methods relatively within reach, and selling prices are high; a major inhibitor at present appears to be the acquisition of seed in sufficient quantities for large scale commercial development. Some work would be useful to reduce costs of grow-out and investigate marketing. Indications are that these problems are surmountable by a variety of means, and as such should be of high priority for research and development.

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Appendix I

Retail Market Price June 5, 1980

Billingsgate Fish Ltd.	$7.59/lb. frozen Eastern
Poseidon Fish Market	$6.99/lb. frozen Eastern
Seven Seas Fish Co. Ltd.	$6.95/lb. frozen Eastern
Save-On Seafoods	None available, on order; hard to get in past. Sold local ones in shell live small 5". Would be interested in local supplier, either shucked or in shell. Would probably get better price for fresh.
B.C. Fish Co.	$6.50/lb. frozen Eastern
Fraser Seafoods	$7.99/lb. frozen Eastern (Get shucked fresh in July-August and the price sometimes comes down).
Pender Seafoods Ltd.	$6.75/lb. frozen Eastern
Sasamat Seafood Market	$8.00/lb. frozen Eastern

Sample size = 7

Mean retail price = $7.25/lb.

Range - $6.50 to $8.00/lb.

N.B. THIS IS FOR FROZEN EASTERN.

It would be expected that this price could be improved by fresh product and appropriate marketing.

Unless otherwise noted above, all telephone respondents said they did not know what price they could get for fresh scallops, but may be interested in trying.

The average 1982 price is $9.00/lb., with some retailing at $11.00/lb.

Appendix II

Estimated Volume of Scallops sold in B.C.

The volume of scallops sold in B.C. was estimated by telephone interviews with three major distributors, twelve wholesalers, and a number of retailers and restaurants in B.C. Estimates were difficult because of complicated product flow patterns and confidentiality reservations in some firms. However, it was estimated that there are perhaps 15 wholesalers in Vancouver selling about 500 lb/week (28,000 lb/yr), for a total of 420,000 lb/yr. plus perhaps three selling five times as much (for a total of another 420,000 lb/yr.) and perhaps an equal amount being sold elsewhere in B.C. The total B.C. sales would then involve about 1.5 million lb/yr., having a landed value of $4.5 million, and a retail value exceeding $10 million per year. A totally independent estimate (J. Ainglin, International Pacific Sales, pers. comm.) was 1.8 million lb/yr., although Mr. Ainglin adds that many estimate errors are probable, so this should be taken as a rough estimate only. The major sources of scallops for B.C., at present, are eastern Canada, Alaska, Iceland, and Brazil.

Appendix III

Quantity and Value of Scallops Exported From Canada in 1978

Source: Statistics Canada

	Country of Destination	Quantity (tonnes)	Value ($,000)
Fresh and Chilled	France	3	22
	United States	937	9,515
Frozen	United Kingdom	4	29
	Denmark	2	13
	France	314	1,866
	West Germany	19	116
	Netherlands	1	5
	Norway	-	1
	Sweden	7	46
	Singapore	-	4
	Australia	-	1
	Bermuda	15	97
	Barbados	1	11
	St. Pierre	2	17
	United States	9,932	64,784

CLAMS

CLAMS

Introduction

There are at least sixteen different species of clams present in the waters of British Columbia. Seven of those species, the razor, butter, horse, cockle, geoduck and both the Manila and native littleneck, are harvested commercially. Markets and demand for B.C. clams are strong and fishing effort and landings have been increasing since 1977.

Many species may be culturable, but at present only the Manila clam (or Japanese littleneck, Tapes philippinarum) is being used in culture. This is due to seed availability and probably to this species' ability to live over a wide intertidal range.

History

Clams have been traditionally fished (dug from beaches) in British Columbia (cf. Quayle and Bourne 1972), with culture activity just beginning at experimental and pilot stages over the last few years. Clams can be cultured by seeding intertidal beaches (population enhancement) with or without protective nets; by holding them in trays in floating culture; and by growing them in tank systems. Interest in culture development is focussed on the Manila clam since some aspects of culture are favourable and demand and prices for this species are better than for other clam species (other commercially utilized species include the native littleneck, often interchangeable with the Japanese littleneck for marketing purposes, the butter clam, the razor clam, cockle, horse clam, and geoduck). The University of Washington's program on Manila clam culture has concluded that seeding and netting is a practical and economically feasible culture method (Anderson and Chew 1980, Miller et al. 1978, Glock and Chew 1979). Other culture methods are used in Asian countries for other clam species (cf Bourne 1981).

Licensing and Jurisdictional

Several licenses to culture clams by seeding beaches are in the application review process. The Federal Department of Fisheries and Oceans (D.F.O.) would be opposed to leasing of traditional digging areas, since these are used by a number of commercial and recreational users.

A perplexing situation is developing with respect to clam harvesting/culture. It appears applicants can receive tracts of foreshore for clam culture which gives them exclusive harvesting rights. As no diligent use criteria have been developed for clam culture the successful applicant could simply continue to harvest the wild clams and claim he was "culturing". This situation has several ramifications, and because of the split jurisdiction the situation could become very awkward. This particular area needs some immediate consideration (Chislett pers. comm.).

It is possible that theft of cultured stocks in accessible inter-tidal areas may be a significant problem.

Growers transferring small clams within leases or wishing to use digging machines will have to make special arrangements with D.F.O. since it is presently illegal to possess undersize clams and to use mechanical harvest devices without permission.

Biological/Technological Research and Needs

B.C. Culture work in progress

Clam Culture Program - Canadian Benthic Ltd.

Canadian Benthic Ltd. are developing culture technology for Manila clams. They purchase seed from Pigeon Point (a U.S. hatchery) at three stages - eyed larvae, 1 mm., and 2 - 4 mm. - in order to assess production costs

using various starting sizes. They are growing them in a stacked tray system, with 20 layers totalling 3 m. in depth. Algae are circulated to the clams through an upwelling system. Hopefully, the clams will reach market size in 10 - 15 months, and they hope production will be profitable at 80¢ a pound. Their greatest problem is with system fouling, which can be avoided to some degree by adjusting the depth of the water system intake. Faecal accumulations are removed through reverse suction.

Pacific Biological Station (P.B.S.) Research

D. Heritage has reported on three to four years of research work on Manila clam culture in the Strait of Georgia. Culture experiments in several Strait of Georgia locations include beach seeding with Manila and butter clams with and without netting protection; mortalities have generally been high without netting, but acceptable when netted (Bourne pers. comm.). Experiments using Nestier trays showed rapid growth but fouling problems occurred. P.B.S. data on these mortalities and conditions should be evaluated and compared to those obtained in the University of Washington work. Such analyses would help to identify environmental conditions and procedures that improve survival and growth of planted and natural seed.

P.B.S. personnel also set a sustainable yield level at Savary Island, which has been periodically closed for conservation reasons. Conservation closures may also be imposed in other areas (e.g. Barkley Sound has been closed for the last two years) (Bourne pers. comm.). Natural clam populations are under study at Seal Island.

D. Heritage has begun an oysters over clams polyculture experiment on Denman Island using protective netting over three plots.

Other points:

a) Growth - Natural populations of Manila and native littlenecks require about 3 years to reach 38 mm. which is the legal size. Butter clams require between 5 and 6 years to reach commercial size (63 mm.) in optimum areas like Barkley Sound and the Strait of Georgia (Bourne 1981).

b) Crab, seastar and scoter duck predation on clams can be serious. For this reason, beach preparation and netting is used in culture.

Markets and Marketing Research Requirements and Economic/Financial

As with most other shellfish, there is little information available on present and potential markets and demand; however, a variety of sources of existing data could be used for initial analyses and evaluations, as follows.

There are considerable quantities of clam fishery products produced in B.C. (see Table 3-1), exported from B.C. ports (most of which are produced in B.C.; see Table 3-2) and imported to B.C. (see Table 3-3). The amounts being imported are relatively stable, while the exports seem to be increasing over recent years. The B.C. clam landings show a marked increase in the last four years over previous years. These trends would indicate a pattern of increasing B.C. production and sales of all clams (all species). For Canada as a whole, clam exports more than doubled between 1976 and 1978 (D.F.O. 1979); the same occurred in B.C. clam exports (see Table 3-2). There is no information on what demand could be expected with increases in supply.

The extent to which the fishery supply could be increased affects the commercial viability of clam culture. Quayle and Bourne (1972) have estimated that sustainable clam harvest in B.C. has a potential of about 2,700 metric tonnes of butter clams, 450 metric tonnes of native littleneck clams, 220 metric tonnes of Manila clams, and 340 metric tonnes of razor clams per year. Estimates of landings and sustainable yields quoted more recently (in Pearse 1982 p. 141) agree with the above estimates. This total, 3,710 metric tonnes, represents more than double the 1980 landings of 1,760 metric tonnes. However, it should be noted that the 1980 landings of Manila and native littleneck clams are approximately at the estimated potential levels; the primary potential increase in landings would be in butter clams, which are presently of lower value than littlenecks. Similarly, in Washington State, prospects for increasing fishery landings of Manila and native littleneck clams are limited, while demand for these two species continues to increase (Ritchie 1977).

In 1980 B.C. landings of 1,760 metric tonnes of clams of all species, excluding geoducks, had a landed value of $1,080,000 and a wholesale value of $2,280,000. The average unit landed value was therefore 74.8¢ per kg. (calculated from data in D.F.O. 1980). There are data (D.F.O. 1980, Ritchie 1977) on relative prices of different clam species and products, which should be further analyzed for estimates of demand and potential profit margins. From this preliminary analysis, however, it is evident that low prices of B.C. clam products are a substantial problem. Comparative average landed prices of B.C. shellfish in 1980 were as follows:

Product	$ per Kg.	
Prawns	5.74	
Shrimp	2.05	
Abalone	6.20	
Crabs	1.68	
Oysters	1.22	- (calculated for shell stock from value given as $5.67 per shucked litre)
Clams	0.75	

(Source D.F.O. 1980).

Nothing is known about how the apparent high demand for littleneck clams would respond to increased prices.

There is a high-priority need to gather and analyze two types of information to evaluate the economic viability of littleneck clam culture:

(1) Markets and demand at different price levels

(2) Costs of production given known components of several culture methods.

Bourne (1981) provides preliminary estimates of costs of production. On this basis, clam culture appears marginally economic.

Conclusions and Recommendations

(1) Manila clam culture research in Washington State has produced techniques which are the logical take-off point for clam culture in British Columbia.

(2) Little is known of clam culture economics in British Columbia but, at present levels of costs and prices, the prospects are dubious. Thus, work contributing to reduction of production costs is of high priority.

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TABLE 3-1 - B. C. CLAM LANDINGS

Year	Total of All Species,* Metric Tonnes	Littlenecks	
		Japanese 1000's of lbs.	Native 1000's of lbs.
1970	1,049	174	320
1971	1,155	338	796
1972	1,560	584	1,391
1973	714	299	455
1974	1,110	402	723
1975	1,173	348	520
1976	1,179	438	382
1977	1,389	869	460
1978	1,587	1,660 (753 m.t.)	351 (159 m.t.)
1979	1,612	553 (251 m.t.)	602 (273 m.t.)
1980	1,632	635 (288 m.t.)	789 (385 m.t.)

Table compiled using data from Fisheries and Oceans, 1970 - 1980, British Columbia catch statistics.

* Includes razor, butter, Japanese littleneck, native littleneck and "mixed clams"; does not include horse clams or geoducks.

TABLE 3-2 - EXPORTS OF FRESH AND FROZEN CLAM PRODUCTS FROM B. C., 1970 - 1978*

Year	Quantity (pounds)	Total Value ($)	Value/lb. ($)
1970	878,700	174,712	.20
1971	1,270,500	256,987	.20
1972	2,003,200	487,904	.24
1973	1,037,500	317,171	.31
1974	1,058,900	404,512	.38
1975	1,228,700	467,949	.38
1976	1,265,400	495,459	.39
1977	2,222,300	1,073,781	.48
1978	2,538,800	1,563,522	.62

* The clam products included in this table could be derived from Eastern Canadian provinces, as well as British Columbia.

Source: External Trade through British Columbia Customs Ports, 1970 to 1978, Department of Economic Development, Province of British Columbia.
(After Fralick and Tillapaugh 1979)
Most of these exports were to U.S.A.

TABLE 3-3 - IMPORTS OF CANNED CLAM PRODUCTS 1970 - 1978*

Year	Quantity (pounds)	Value** ($)	Value ($/lb.)
1970	1,567,000	458,059	.29
1971	1,131,400	330,733	.29
1972	1,481,900	478,900	.32
1973	1,866,700	769,811	.41
1974	1,709,500	870,423	.51
1975	1,183,000	635,011	.54
1976	1,614,400	943,189	.58
1977	1,827,000	1,611,786	.88
1978	1,542,800	1,722,493	.90

* These products were imported through British Columbia customs ports, and all were not necessarily consumed in British Columbia; that is, they may have subsequently been shipped out of B.C.

** The value is the F.O.B. price from the importing nation, converted to Canadian dollars. These values should be viewed as a relative trend, rather than compared directly to B.C. products.

Source: External Trade through British Columbia Customs Ports, 1970 to 1978, Department of Economic Development, Province of British Columbia. (After Fralick and Tillapaugh 1979).

Above imports primarily from Japan, People's Republic of China, South Korea, U.S.A.

MUSSELS

MUSSELS

Introduction

A number of attempts at mussel (Mytilus edulis) culture in British Columbia, at commercial and experimental scales, have met with substantial biological and technological problems. Considerable work is in progress on resolving these problems. Fishery production of mussels is minimal.

Biological/Technological Research and Future Needs

Although there is extensive experience in commercial cultured production elsewhere, and in experimental and pilot-scale commercial production in B.C. (cf. Quayle 1978), substantial biological and technological problems remain (Gibbons 1982). Seed sources for mussel culture are numerous and plentiful in B.C., and a number of collection methods have been developed including estimates of costs for each method (Gibbons 1982). However, grow-out attempts have met with heavy losses from summer die-off sluffing. Partial or full solutions may be found (Gibbons 1982) by keeping mussels at deeper levels of the water column (perhaps 5 - 10 m) to avoid fouling, duck predation and summer die-offs; however, these problems require investigation. Further, minimization of handling by grow-out on seed collection elements directly may reduce sluffing losses and weak byssus incidence, as well as reduce labour costs.

There is considerable interest in investigating the potential of growing the California mussel (Mytilus californianus) by culture in B.C. Insufficient information exists to evaluate this potential at present.

B.C. Culture Research in Progress

Pacific Biological Station Work

D. Heritage reported on his research program in mussel culture. He has tried mussel grow-out in nine test sites in Southern B.C. using the "socking" method recommended by Quayle (1978). He has observed substantial problems with sluffing and summer mortalities, but it is

not known what environmental conditions, which may well be site-specific, correlate with the higher mortalities. Such analyses should be performed on these data, since other research does not include a substantial number of sites; this may help to identify conditions that induce or aggravate summer mortality (see below).

Redonda Sea Farms Work

Redonda Sea Farms (RSF) has completed two years of work and is continuing in a third year of commercial evaluation of mussel culture, funded by a joint Federal-Provincial grant. Two reports on the work are available (Gibbons 1981, 1982). The work was to include all aspects through to marketing; however, biological problems have caused essentially total crop losses. Consequently, present work is focussed on biological and culture technology aspects. Major problems included duck predation (which appears to have been solved by holding mussels at greater depths (5 - 10 meters being tried at present) and by providing a sacrifice crop near the surface; problems with the sock method (collection of seed and grow-out on ropes has been substituted); and summer mortality (grow-out at greater depths may be a solution). Unfortunately, observations this summer (1982) indicate that, at least at Refuge Cove, grow-out at 5 - 10 m. does not solve the summer mortality problem. It is possible that the mortalities are caused and/or aggravated by high temperatures and low salinities, which are common at Refuge Cove even at these depths (U.B.C. scallop project data). There are indications in the literature (e.g., Reish and Ryers 1968, Van Winkle 1970) that these environmental factors affect survival and byssus attachment formation, although it is possible that other factors (e.g., handling, parasites and diseases, food shortages) are implicated in summer mortalities as well. For these reasons, it would be important to evaluate data on mortalities and co-occurring environmental conditions at a number of sites. These data include the Pacific Biological Station work above, as well as several sources of data in the U.S. and Eastern Canada (see Gibbons 1982). It is possible that such an examination of existing data could be profitably conducted, at least in bringing unpublished specific data together, in a second workshop on mussels.

If the data exists, statistical analyses could follow. If the existing sources do not include appropriate environmental data, it would be important to gather such data in more basic experimental work.

Archipelago Marine Research (A.M.R.)

(a) Mussel Farm History

In 1981, A.M.R. developed a mussel mariculture facility in Bamfield, B.C. with wage subsidy assistance from the Federal government (Employment and Immigration Commission, New Technology Employment Program). The objectives of the one-year program were to: (i) conduct a literature survey of existing suspended culture technology and mussel biology; (ii) construct and operate a long-line culture system; (iii) monitor growth and condition factor of cultured mussels at a variety of locations in Barkley Sound; (iv) identify existing local markets (wholesale and retail) and examine various processing options for mussels; and (v) conduct an economic assessment of production costs.

At the completion of the year-long program, the culture system was in full operation with an anticipated production stock of 20 tons. However, through the winter of 1981/82, intense predation by migratory scoters virtually eliminated the production stock. Since then, operations at the mussel farm have been scaled down with efforts re-directed toward areas which present a major obstacle in applying mussel culture technology to the B.C. coast: (1) duck predation, (2) summer mortality. The former problem is presently being examined using an assortment of duck avoidance measures such as hydro-acoustics and the use of net pens. The second item, summer mortality, is also under study at the A.M.R. mariculture facility in Bamfield.

(b) Summer Mortality in Mussels

At certain culture sites in B.C. and Washington, large scale mortality of mussels occurs during the second summer of growth. Pilot culture sites at Refuge Cove, Redonda Island and Departure Bay have shown such mortalities, as well as areas in southern Puget Sound and the east coast of the United States (Incze et al. 1980). These mortalities occur locally in late summer, after the peak in summer water temperatures, and are often characterized by a weakening of the byssus thread attachments and a sluffing of mussels from the grow-out medium.

In April of 1982, A.M.R. initiated a program to monitor mussel growth and mortality in Departure Bay and Barkley Sound with funding from the B.C. Science Council. This study is attempting to correlate certain environmental parameters, such as water temperature, salinity, dissolved oxygen, chlorophyll concentration, particulate size and density, with various measures of condition in mussels (lipid, glycogen, protein, and condition factor). The hope is to identify the environmental cues and consequent physiological manifestations which lead to large scale mortality of mussels during the summer months. This monitoring program is intended to continue through the summer of 1983.

Demands and Markets

Additional information regarding the economic feasibility of mussel culture in British Columbia is needed. Information is needed on:

1) production costs, 2) wholesale and retail prices, and 3) market demand.

The following preliminary information has been compiled by Archipelago Marine Research (unpublished data) and Gibbons (1982).

Estimates of Local Demand (1981)

a) Fresh Product (actual numbers based on telephone survey of wholesalers)

Vancouver	104 tons/year
Victoria	26 tons/year
Total	130 tons/year

b) Canned or Smoked

No estimate is available for local demand presently for canned or smoked mussels. This type of product is the most readily available source of mussels for local consumers.

Processing

A.M.R. in conjunction with Baynes Sound Oyster Co., attempted a cursory examination in March 1982 of the economic possibility of producing a canned smoked product. The goals of this inquiry were to identify the processing parameters required to produce a smoked product, and the major cost areas encountered. Four hundred pounds of cultured shell stock were shipped to the processing plant and various procedures of sorting, cleaning, cooking and shucking were tried.

The total estimated cost of producing 640 two-and-a-half ounce cans was $1.29/can, of which $0.80 represented the labour component.

The processing procedures involved in the production of canned smoked mussels required extensive manual labour input (100 lbs. required 85 man-hours to produce). It is felt that this type of secondary processing can be made amenable to a mussel culture operation by reducing the labour component cost via the utilization of appropriate processing machinery. During the investigation, a 4:1 weight relationship of raw shellstock to cooked meat was discovered.

B.C. Production

Cultured	1.4 tons	(A.M.R. catch statistics book, 1981)
Wild	2.0 tons	(Fisheries catch statistics 1980/81)
Total	3.4 tons	

Wholesale and Retail Prices

(a) Wholesale in Vancouver (1981):

$0.80 - $1.00/lb. for locally cultured mussels

$0.71 (C) /lb. F.O.B. Boston (Gibbons 1981)

(b) Wholesale - Atlantic Seaboard:

$0.67 (C) /lb. (Gibbons 1982)

(c) Retail in Vancouver:

$1.69 - $2.19/lb. (Gibbons 1982)

(d) Retail in Seattle:

$2.40 (C) /lb. (Waterstrath in Gibbons 1982)

Other Production Areas

U.S. East Coast (1977)	1,500 tons/year (Lutz 1980)
Projected U.S. Mussel Production (1981)	3,400 tons/year (Lutz 1980)
Nova Scotia (1980)	186 tons/year (D.F.O. catch statistics)

At the present time, production of mussels in B.C. accounts for approximately 3% of the estimated demand. At the present level of production, demand is met through imports from suppliers in Eastern North America. It is difficult to speculate how an increased supply from local producers would influence demand. A restaurant information survey conducted by Waterstrath (in Fralick and Tillapaugh 1979) in Washington indicated that, of those responding, most would be willing to serve mussels, although less than 10% ever had, and 60% were concerned about poor consumer demand. Priority should be directed towards studying the effect of market promotion on local demand, and to evaluate the potential for export.

At the present level of mussel culture in British Columbia, it is difficult to accurately assess production costs. Production costs cannot be accurately determined as they vary considerably according to culture methods employed and access to markets. Using a production estimate of $0.70 - $0.80/lb. (A.M.R. unpublished data), the economic viability of mussel culture may not be as favourable as other cultured shellfish. Gibbons (1982) indicated that it would be difficult to increase selling prices as west coast prices are already greater than those in the east coast of North America. Estimation and evaluation of production costs should await the solution of biological and technological problems, since these could markedly influence costs of culturing mussels.

Conclusions and Recommendations

The potential to culture mussels commercially in B.C. appears to be favourable on some bases and questionable on other criteria. Sources of seed are not a problem, extensive international experience exists to draw on, and demand may be favourable. However, summer mortalities and predation are a serious impediment to grow-out in at least some sites, and little is known about potential profit margins.

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ABALONE

ABALONE

Introduction

The propagation and culture of the Northern Abalone (Haliotis kamtschatkana) in British Columbia is only just beginning. Although abalone were accidently spawned at the Pacific Biological Station in Nanaimo some years ago, the first systematic propagation work is presently being carried out by Pacific Trident Mariculture Ltd. (P.T.M.L.). This is the first attempt at a commercial hatchery and grow-out operation in British Columbia, although there is a further hatchery in the planning stage by Ablab Ltd., Powell River.

Culture systems discussed include free range ocean bottom grazing, bottom enclosures, floating pen culture, and polyculture in closed circuit systems. In addition, proposals have been made to enhance natural stocks with hatchery-produced seed.

History

At present, all abalone produced in British Columbia are caught by sports or commercial fishermen, mostly by diving. Pearse (1982) gives a good summary of the history of this fishery and the quota and licensing system now in effect.

Abalone culture began in Japan, with research effort being concentrated on methods of wild stock enhancement. Harvest rates are estimated to range from 5% to 25% of those outplanted, depending on seed size and planting season. Japanese hatchery production is around 3 million seeds (25 mm and larger) per year. Production of market-sized abalone in Japan is around 5,500 tons per year (Rosenberry 1982).

California has also become very active in abalone culture. In 1982, the California Department of Fish and Game budgeted $250,000 for abalone enhancement. In 1981, seed costs were U.S. $0.70 to $1.00 per 25 mm animal (Rosenberry 1982). There are now a number of abalone hatcheries either producing or being planned in California.

Licensing and Jurisdictional

There do not appear to be any serious licensing or jurisdictional problems facing abalone culture in British Columbia. It had been felt that the sale of animals of less than 100 mm would be difficult, but the Department of Fisheries and Oceans (D.F.O.) are prepared to look at different size regulations for culture operations, as they already have for trout and salmon (Wilson pers. comm.).

It had also been reported by Whyte (pers. comm.) that the B.C. Ministry of Lands, Parks and Housing was reluctant to lease deep water areas; however, the Ministry's Nanaimo office reports that they would be prepared to enter into such leases (Anderson pers. comm.).

Concern has, however, been expressed by abalone growers that the transfer of seed (under-sized animals) from hatchery to grow-out sites is not allowed for in present D.F.O. regulations. This problem is presently being discussed between abalone hatcheries and the D.F.O. Shellfish Committee.

The recommendations of Pearse (1982) call strongly for abalone fishermen to be given mariculture licenses that would include exclusive harvest rights in addition to their quotas. The license holder would presumably be expected to reseed his area with hatchery-produced seed.

Biological/Technological Research and Future Needs

P.T.M.L. has been awarded a contract by the Department of Supply and Services entitled "Generation of Scientific Information and Development of Technical Advances in the Field of Abalone Mariculture". In particular, to:

- find the most effective means to condition adult abalone to sexual maturity;
- compare existing spawning methods;
- investigate settlement in veligers;
- reduce grow-out mortalities to a minimum.

Canadian Benthic Ltd. are measuring comparative abalone growth rates in wild stock sampled from Barkley Sound. While they do not have access to large sample sizes, their initial results appear to duplicate those of Quayle (1971). Abalone are also being used as diatom grazers in closed circuit clam culture studies (Saunders pers. comm.).

As abalone growing is in its infancy in British Columbia, the full range of culture and growing systems are subject to ongoing research and development by those engaged in hatchery and culture work. The role of research funding institutions in this process is unclear as there is a degree of proprietary information being developed by those engaged.

Abalone hatchery operators would like to see D.F.O. consider abalone population enhancement experiments using hatchery-produced seed along the lines of the work being carried out in California. Controlled bottom culture, which would include predator control, is also in need of investigation. Although this technique has been widely used in Japan for some time, the results show wide variability (Seki pers. comm.). Conclusions as to economics and methods are only now being arrived at (see Appendix I).

A further area in need of research is cost information for seed production. As spawning and larval rearing techniques are improved, it will be important to establish accurate production costs for different sized seed abalone. Both P.T.M.L. and Ablab have volunteered to help in such a study.

Economic/Financial

Considerable interest is being expressed in abalone culture in British Columbia by both fishermen and hatchery operations (cf Pearse 1982). While the results from Japan and California are encouraging, this experience cannot be directly applied to British Columbia, as different species of abalone are being cultured, within different economic, biological and legal frameworks, e.g., the absence of sport diving in Japan.

Japanese researchers, with experience in the outplanting of hatchery-produced seed, admit that they do not have detailed cost-benefit information of outplanting (Seki pers. comm.). If final recoveries are low, the initial seed cost will be of cardinal importance in determining the profitability of stock enhancement.

In addition, Japanese abalone hatchery techniques appear to be very labour-intensive; for local seed production to be profitable, labour costs will need to be reduced to a minimum. P.T.M.L. report that their hatchery methods are "hybridized from the California and Japanese hatcheries ..... we are fairly certain that we can find ways to decrease the labour input." (R.G. Whyte pers. comm.).

The pioneering work of P.T.M.L. will be watched with interest as they determine profitable hatchery and grow-out methods.

Markets and Marketing Research Requirements

No specific market or marketing research needs have been cited by abalone growers as items for immediate attention. It is felt that a large domestic market exists and that export possibilities are excellent. A market does need to be developed for a 2-year old cocktail abalone, which would yield around 30 pieces of meat per kilogram (meat recovery from shellstock is about 30%).

Live 100 mm abalone command very high prices in Tokyo due to the high-priced sushi market and the large number of servings possible from each animal, although it has been difficult for B.C. exporters to attain high prices for wild harvested abalone in this market (Whyte pers. comm.).

In California, live, wholesale prices are around $24 per pound at this time, although Michael Aley of Americulture Ltd. expects to "drive prices to about half what they are now or about $12 per pound in the next decade." (Rosenberry 1982).

There is presently a large gap between what sellers of B.C. wild harvest abalone would like to receive and what they have been offered in Oregon and California (MacDonald pers. comm.). At present, there is much anecdotal information about abalone prices, which cannot be checked.

Conclusions and Recommendations

The relatively slow growing time of juvenile abalone will mean that some years will be required to solve the research needs identified above, that is, for the work being carried out by P.T.M.L. and others, to reach a point where it can be applied on a large scale; or where sufficient seed for outplanting is available for independent growers.

Until this happens, it is extremely difficult to make statements about the potential of abalone culture in British Columbia, although slow growth is a problem. Meanwhile, it would appear that the following things should happen:

- shellstock holding and transfer policies for under-sized abalone be developed by D.F.O.;
- the numerous questions of leasing (licensing) raised by Pearse and the industry be settled with the Ministry of Lands, Parks and Housing;

- market research should continue, especially to develop cocktail markets as product comes on-stream.

Those growers getting established are watching carefully developments in California and, when possible, Japan. It would seem that this must continue so that foreign technical and market questions and solutions are known.

As the price of abalone seed will be a key component in the economics of abalone enhancement or fishing/mariculture lease operations, the true costs of hatchery seed production need to be determined once techniques are established.

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APPENDIX I

Notes on Japanese abalone culture techniques

Mr. Tetsuo Seki, a leading Japanese abalone researcher, gave an excellent summary of abalone rearing systems at the Oyster Research Institute (see reference Seki 1980).

Japanese hatchery techniques are well established, to a degree proprietary, and are being successfully adapted to British Columbia. Diatom rearing generally takes place in above-ground, closed system tanks using pumped filtered water. The abalone reside on plastic habitats on which diatoms have been allowed to grow. The sorting and thinning of animals and the cleaning of equipment appears to be quite labour-intensive.

In 1981, the Tohoku Oyster Research Institute calculated their seed growing costs to be 1.9¢ per mm; or a 20 mm animal, when shipped to a rearing cooperative, would need to be sold for 40¢ to pay the Institute's costs. It was reported that, at the sea pen stage of growth, abalone eat 10% of their body weight daily; thus a source of kelp within reasonable proximity to the farm is important (Seki pers. comm).

The transporting of abalone seed occurs after the juveniles have attained 20 mm, when they are sold to fisheries, cooperatives, or other buyers who may transplant them to nature immediately, or keep the abalone longer in intermediate culture (Hovis pers. comm.).

SALMON

PEN SALMON

Introduction

The coast of British Columbia offers considerable potential for the culture of salmon in floating net pens. Existing farmers are concentrating on the production of coho and chinook salmon in a 15-month or more production cycle, which yields a fish of 230 grams or more dressed weight.

History

The development of farming of salmon and trout was a natural outgrowth of the high level of biological knowledge of the two species. Salmon farming in floating net pens seems to have developed from sea trout farming in Norway, and in Japan from that country's overall mariculture development.

The large body of Pacific salmon hatchery knowledge in Canada and the U.S. helped the growth of the industry on the U.S. West Coast and later in B.C. (cf. MacCrimmon et. al. 1974 pp. 55-62). By 1973, several firms were active in Washington, and early experimental work by the Pacific Biological Station in Nanaimo (P.B.S.) and by private firms was underway in British Columbia. Since then, British Columbia production has been increasing.

Table 6-1 - British Columbia Pen Salmon Sales and Firms Licensed 1975-1981

Year	Metric Tonnes	No. of Firms Licensed
1975	0.5	3
1976	1.4	5
1977	7.0	4
1978	13.0	3
1979	38.0	6
1980	146.0	6
1981	176.0	7

Source: Marine Resources Branch

In 1981, "only 4 out of 7 reported any sales and individually they accounted for 76.2%, 17.5%, 5.3% and 1% of total sales" (Sunde 1982).

At present, the industry is concentrated in two areas: the Alberni Inlet and the Sunshine Coast. There appears to have been only one potentially significant new entrant in the past two years, while an early pioneer firm in Indian Arm is presently inactive.

The industry is presently unorganized, with little interaction and cooperation among participants. No joint promotional, marketing or lobbying work has been carried out.

British Columbia production is concentrated on coho and chinook. The chinook is hardy with less mortality than coho, although the rate of growth is a little slower than coho (Hope pers. comm.). The ability to withstand disease is about equal for both species and no market preferences seem to have emerged yet (Priest pers. comm.). Coho production is probably restricted to pan size because of their tendency to mature in the second year. Little work has been done with chum salmon but the results look promising, with good growth rates, despite some problems with diet still to be solved (Hope pers. comm.).

This view is not shared by other researchers as chum (and pink) salmon are subject to Pen disease, for which there is no vaccine or particularly effective antibiotic. Experience at the Pacific Biological Station has also shown that chum salmon were particularly vulnerable to kidney disease (which shows up in later life), and to Chaetoceros (a spiny alga which irritates the gills of salmon) (Brett pers. comm.). Until significant numbers are reared to pan size and the market is tested, the biological inhibitions mentioned above suggest that chum salmon are a poor candidate for pen culture.

Licensing and Jurisdictional

The licensing requirements and problems facing salmon farmers are the most severe of any existing British Columbia mariculture group. It has been reported that one farmer presently holds in excess of 20 licenses/ permits, etc. (Hope pers. comm.), although these will vary depending upon site, upland ownership and the existence of processing facilities. Existing salmon growers do not report undue problems with obtaining licenses (provided patience is shown), but most of them went through the process four or five years ago.

Problems are being experienced in common with other species groups; these include lease tenure terms and upland owners. A new issue which has been mentioned is that, due to the possibility of disease transfer, there is a need to restrict the development of new salmon farms in close proximity to existing farms. This will require the inter-departmental cooperation of Marine Resources Branch and the B.C. Ministry of Lands, Parks and Housing, as well as an awareness of the potential problem by the federal Department of Fisheries and Oceans. There is perhaps no need to engrave this requirement in stone; at present, two operations comfortably share San Mateo Bay (Alberni Inlet) without undue biological problems (Shaw pers. comm.).

The attitude and future reliability of the Fisheries and Oceans hatcheries with regard to egg supply is of concern to salmon growers. At present, first priority is given to supplying Salmonid Enhancement Program (S.E.P.) hatcheries with eggs, with the result that fish farmers often receive a late start, sometimes with eggs of doubtful quality, according to some farmers. All growers complain of years when shortages have occurred, particularly of chinook eggs. This seems to be restricting pen salmon production. Growers will gradually develop their own broodstock in response to this problem. Some growers are also raising objections to the price charged for eggs.

Biological/Technological Research and Future Needs

The first priority is funding for continued research. This requirement applies particularly to the continued availability of research and analysis capability of Fisheries and Oceans, at both P.B.S. and at the West Vancouver laboratory. One of the critical risks facing salmon farmers is stock diseases, which can cause large losses very quickly. The reduction of this risk requires stable funding for disease research and analysis, and extension work staff at P.B.S. including, where necessary, emergency travel funds to allow on-site visits in critical situations. A strong case can be made for increased funding in this area if salmon farming is to expand, although the need for vigilance and good equipment on the part of the farmer should not be forgotten in disease control. Related to this is the important advisory role of P.B.S. staff in Federal hatchery egg production, which is of critical importance to salmon farmers.

Feed costs and feed efficiency are the second critical factor in profitable salmon farming. The West Vancouver laboratory could contribute work on feed useful to salmon farmers (Slind pers. comm.); in the past, much of their work has been directed either toward ocean survival and fecundity of hatchery-released fish, or to fresh water diets. What is needed is nutrition information to help farmers maximize both growth and disease resistance in various marine habitats.

There is a need to effectively translate research work on feed nutrition to the production of locally-produced feeds which meet the criteria arrived at by the research.

At present, the feed situation seems somewhat unsatisfactory. A feed acceptable to some farmers is being produced in British Columbia, although the relatively small order sizes have led to inconsistencies among batches. This has understandably annoyed some growers so that they have turned to Moore Clark Ltd. in Washington. Taxes and duties have to be paid on the feed imports. It is unclear to what extent existing B.C. feed mills using local herring meal can be persuaded to produce high quality feed conforming to criteria arrived at by research and at competitive prices to the U.S. imports. Research effort, reasonably priced local herring, and a high degree of industry cooperation will all be required to solve this problem.

Work is also needed in the third critical area of broodstock supply and quality. The qualities desired for hatchery operations are not the same as those for farming operations. High quality farm broodstock should have the ability to grow quickly with good shape, be resistant to disease, and be able to withstand crowding. Genetic work on these characteristics has the potential for great pay-offs, provided that salmon broodstock can be economically held and reared to allow selection to take place, and provided that satisfactory "security" arrangements can be shown to Fisheries and Oceans to ensure the "genetic integrity" of wild stock. However, there is some question as to the ability of private growers to maintain desirable strains given the small numbers of fish they will be using. One large public or private hatchery may be the solution (Fralick pers. comm.). It is this type of hatchery and fry supply initiatives which have contributed to Norwegian salmonid farming success.

It would seem that much more systematic work is required in the area of fry rearing techniques, and in optimum flushing rates, temperature, salinity and diet for best growth. Although much of this research would be fairly site specific, enough generally useful information could emerge to warrant public expense, especially if linked to needed nutrition research. More work is also needed on plankton concentration methods to improve fry feed conversion ratios.

The possibility of sea trout "steelhead" culture, on an alternate cycle to salmon, offers potential for reducing capital costs per unit of output. Steelhead have higher temperature tolerance, but require longer in the hatchery. Such combined production would allow year-round crews to be employed, and would allow better use of hatchery and pens, as well as providing product for summer markets. The selling price for steelhead in the range of $2.50 per Kg. appears high enough to encourage a pilot development. M.R.B. has funded research into broodstock, nutrition, low cost feed and genetics, with the aim of seeking alternative salmonid products for fish mariculturists (Fralick pers. comm.). Interest is presently being shown in this possibility by several growers, although it may be difficult to differentiate sea-grown trout from lower priced land-farmed trout.

Use of labour saving devices has increased the average Norwegian output to 25 tons per man per year (Slind pers. comm.). Development and application of such techniques in British Columbia require research effort, particularly to ensure compatibility with acceptable egg-to-maturity survival ratios, and with maximum food usage and high finished quality standards.

It has been suggested by farmers that the following areas of technology require work. These are not exhaustive and are in no particular order:

- non stressful biomass estimation methods
- automatic feeders which are cost effective and accurate
- efficient and non stressful sorting, vaccinating and harvesting methods
- pen transfer techniques or equipment
- aspects of pen design e.g., use of antifouling paint, cost effective designs and the effect of light and shade areas
- killing and eviscerating machinery.

Markets and Marketing Research Requirements

Pen salmon growers have basic market research or market information problems, such as where markets are, how big they are, and what size fish they require.

Initially, cultured salmon production appeared to be aiming at a pen-sized (approximately 250 - 450 g.) winter market, i.e., after a 15-plus month production cycle commencing in November. Apex-Bio Resources Ltd., which, until its bankruptcy, was the largest grower with 76% of B.C. sales in 1981, targeted the majority of its production to the U.S. market (Wilkes pers.comm.). It is unclear if this decision was based solely on that market's size and extensive broker/wholesaler network, or if it was felt that the Canadian market could not absorb the Apex-Bio production.

Others feel that the Canadian market should be pursued further as well as developing the U.S. market (MacDonald pers. comm.), and that gourmet restaurant sales need to be developed for pan-sized, as well as supermarket take home sales for both pan-size and larger fresh and frozen farmed production. Industry sources estimate that over 50% of B.C. pen salmon production has, up to now, been sold in Canada.

Little information is available as to the size of the Canadian market for this product.

Table 6-2 presents data on sales of pan-sized salmon and trout in British Columbia. These could form the basis for an evaluation of demand for pan-sized salmon if additional information were obtained on interchangeability of the products and production outlook for trout.

Table 6-2 - Sales and Imports

Total Imports and Sales of British Columbia-Produced Pan-Size Salmon and Trout

Year	Trout Imports Japan Kg.	Trout Imports U.S. Kg.	B.C. Trout Sales (Food) Kg.	B.C. Pan-size Salmon (Food) Sales Kg.	Total Sales Kg.
1974	266,091	14,818	N/A	N/A	280,909
1975	106,636	30,773	41,819	364	179,592
1976	61,091	37,227	41,200	1,367	140,885
1977	100,682	86,955	57,971	6,905	252,513
1978	175,091	47,955	54,419	12,897	290,362
1979	168,740	41,280	52,723	38,499	301,242
1980	114,701	139,701	55,711	146,504	456,617
1981	38,021	171,506	71,294	176,382	457,203

Source Marine Resources Branch

Marketing and production ideas have changed for some salmon growers following the success achieved with larger fish (N.B. conversion ratios improve with size), and with the increasing acceptance of pan-size salmon in summer. The latter are successfully competing with steaks of wild-caught salmon, while larger fish are moving well from December through late March/April (Priest pers. comm.).

The most important export market for British Columbia cultured salmon has been the United States, where Apex-Bio Resources Ltd. traditionally sold the bulk of its production. The growers in Washington are the only producers of cultured salmon in the U.S. Domsea Farms, the Washington industry leader, has traditionally sold much of its production frozen, but recently began to change its strategy to more fresh product in its sales mix. It is unclear what the result of this will be to British Columbia growers presently shipping into the United States.

A further difficulty with the U.S. market is the competition from Norwegian-farmed Atlantic salmon. Sales of this product in 1981 were 820,000 Kg. (Bromley pers. comm.). With reported changes within the European Economic Community around fresh fish sales, and continued production increases in Norway, it is likely that the U.S. and Canada are targeted markets.

B.C. pen salmon culture would appear to be subject to potential future competition from terminal fishery production, and more particularly ocean ranching (cf. Pearse 1982). This risk becomes more serious as pen salmon firms begin selling a greater proportion of their crop as larger fish, and as pressure to begin private ranching intensifies. The significance of this is hard to assess from the U.S. experience. Ranching operations in Oregon have not met expectations, but those in Alaska have achieved repeated success (Gordon 1982).

The formation of pilot, small scale/low technology ocean ranching projects in British Columbia would place existing pen growers, with fry raising experience, at some advantage, if horizontal integration is acceptable under whatever licensing scheme is put in place. Indeed, ocean ranching may provide the necessary elements to achieve economic viability for farmers/ranchers with farmed production constituting the value-added, specialty products (Fralick pers. comm.).

Turning to other marketing issues, there is general agreement among farmers that consistent product quality is of the utmost importance. Measures to maintain this are more difficult to agree on. Gill-tagging with farm of origin has been suggested. The consumer is the ultimate arbitrator of quality but, as with all mariculture products, there is a need to educate consumers on quality. However, how to go about this has not been solved. At present, the same quality standards apply to farmed salmon as to wild-caught salmon. The industry feels the imposition of additional standards would have no advantages and many disadvantages at this time.

Existing marketing techniques depend largely on firm size and range from small deliveries to restaurants, to standing contracts (both retail and wholesale) to brokers and U.S. agents. Small growers are concentrating on finding markets as their production increases. Part of the reason for Apex-Bio Resources' failure can be traced to over-production and a lack of sufficient fresh markets during winter and spring; thus, there are obvious drawbacks to this production-before-markets approach. Smoked products are being developed by growers unable to sell to their pre-summer sales targets.

As quality/size and presentation become more consistent, it seems likely that some sort of joint advertising/marketing endeavours will be undertaken, although some initiatives may have to await a more formal industry association, and more uniform product quality among growers.

Economic/Financial

The economic aspects of salmon farming have been extensively covered by Fralick (1980), and no attempt needs to be made here to rework his findings. Generally speaking, existing growers could find no fault with Fralick's proportions, i.e., the ratio of costs to revenue. However, the absolute costs and revenue have changed upward from his 1979 estimates, with feed costs having increased very slowly. This should improve the economic viability of pen salmon farming. It is interesting to note that one experienced farmer is using a modified Fralick model as the basis for a study to determine the feasibility of a new site.

By 1982, sales revenues for fresh fish were generally more than $6.00 per Kg. (dressed), while frozen was selling at around $5.00 per Kg. Present feed costs are .77¢ per Kg. (F.O.B. Nanaimo) or .64¢ per Kg. (F.O.B. Washington). One farmer estimates that his feed costs are approximately $1.30 per Kg. of fish produced. The equivalent prices and costs from the Fralick model were fresh sales at $3.75 per Kg., frozen at $3.52 per Kg., and feed at .69¢ per Kg. to .90¢ per Kg. depending on type, or .72¢ per Kg. of fish produced.

Economies of scale are certainly present in salmon pen farming, with a minimum economic unit employing about 3 people and theoretically capable of producing up to 45 metric tonnes per annum. Fralick's model makes the capitalization and cash requirements very clear. His analysis is based on a theoretical farm which would begin production using 750,000 eggs in November and produce 510,204 marketable fish 15 months later (Fralick 1979). Such a farm needed $139,976 in capital, with annual operating costs of $275,761.

The importance of adequate working capital, as well as longer term capital funds, has been confirmed by existing growers. The expansion of the Agricultural Credit Act to include fish farmers has not been widely used so far. One operator was rejected on the basis that the commercial bank would not make sufficient profit on the loan; however, other applicants have been successful after some initial difficulties.

To date, the pen salmon industry seems to have used a wide variety of sources of finance - personal equity, internal cash flow, shareholders/minority venture capital, bank loans, and partnerships. All of these have pros and cons, with none apparently having a special advantage. A grower wishing to retain equity and ownership does seem to be in a difficult position without some form of expansion in Agricultural Credit type loans.

Summary of Conclusions and Recommendations

1. Government must continue to act positively to advance this fledgling industry.

2. If ocean ranching of salmon is to be encouraged and licensed, existing pen salmon growers should have an opportunity to obtain a license.

3. Those biological and technological research recommendations which have been identified by industry should form the basis for future research effort:
   - improvement of egg supply situation
   - continued funding of government research effort
   - feed research and development
   - broodstock and genetic research
   - fry rearing research
   - development of labour-saving technology
   - reduction of stress and fish losses when sorting, vaccinating and harvesting
   - pen design research

4. Other important problems include:
   - streamlining of licensing procedures
   - provision of long-term capital

- market research on size, locations, and products, concentrating initially on establishing the size of the Canadian market and on techniques to reach and expand this market.

5. Regular meetings among industry members would help in the exchange of information, research results, and working toward product consistency and standards.

The coast of British Columbia offers considerable potential for pen salmon culture. Without major technological breakthroughs in such areas as feed enhancement or genetics, industry sources estimate that British Columbia production could reach 1,500 metric tonnes per annum by 1990 (Hope pers. comm.), from a present level of approximately 176 metric tonnes per annum. Fralick states that the probable maximum production for pan-sized salmonids is 1,000 metric tonnes per annum, plus an uncertain quantity of larger farmed salmonids (Fralick pers. comm.). Abundant sites suitable for salmon farming exist, although good fresh water hatchery locations may ultimately constrain expansion unless or until hatcheries are centralized and fry transported to farm sites. M.R.B. has made preliminary estimates of suitable locations in the southern part of the coast of British Columbia.

With an industry-coordinated research and development effort and progressive policy initiatives from government, such production figures are not beyond possibility, although increased production facilities will need to be brought on-stream within the next few years to meet this target. The main constraints to increased production are probably capital, technically-knowledgeable people, proven profitability, and markets. Profits have been slow in coming to the small operators; however, small, efficient family farms, with few employees, are achieving high quality standards. Output per person employed is edging toward 15 tons per person per year, or a gross value of $90,000 (at $6 per kg.) (Hope pers. comm.); these figures are much higher than for any other mariculture species presently farmed in British columbia.

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APPENDIX I

Salmon aquaculture in the State of Washington:

Pen culture of salmon in Washington is confined to the Puget Sound area.

In 1979, there were 14 producers of chum salmon, 6 of coho, 3 of chinook and 1 of sockeye (State of Washington, Department of Fisheries). Most of these are Indian tribal ocean ranching operations. It would also appear that fish returning to Indian-owned ocean ranching operations are also being included in Table 6-3.

Table 6-3 - Landings of Aquaculture Salmon in the State of Washington

	(Metric Tonnes)
1971	4.45
1972	58.75
1973	16.28
1974	209.62
1975	30.25
1976	178.89
1977	130.90
1978	196.09
1979	760.40
1980	392.18
1981	873.18

(Source: Washington State Department of Natural Resources).

The largest culture operation is Domsea Farms Inc. This operation has been owned by at least two large corporations, but has not shown proof of profitability (Brett pers. comm). Indian tribal operations, which were early pioneers in impoundment culture (Lummi) and pen culture (Small Tribes of Western Washington, Saxquin Island), have now largely switched emphasis from cultured production to release for ranching or sports fishing enhancement (Heath pers. comm.). More effort should be made in assessing the competitive position and profitability of Washington pen culture operations.

MARINE PLANTS

MARINE PLANTS

Introduction

The marine plants which are considered to have economic potential in British Columbia are all macrophytic algal species. These include species of brown algae (Laminaria spp., Cymathere triplicata, Nereocystis leutkana and Macrocystis integrifolia, for example) and red algae (e.g., Gracilaria spp., Porphyra spp., Iridaea spp.).

The commercial potential of brown algae is based on their possible use as food and as a source for the colloid "algin". Laminaria spp. are the best known of the brown algae for their food value -- they are commonly referred to in the Orient, where their use is most widespread, as "kombu" or "haidai". Cymathere triplicata is also called "kombu" in Japan, but it is not utilized to the same extent as Laminaria. Another species which is in common use as a food in Japan is Undaria pinnatifida, referred to as "wakame". U. pinnatifida is not found in B.C. waters, but it has been suggested that Alaria or young Nereocystis are comparable (Mumford 1980). Macrocystis and Nereocystis are the types of brown algae which have been used in the trial production of kelp meal (from harvested wild stocks). Macrocystis integrifolia is also used in the production of herring roe-on-kelp ("kazinoku kombu" or "komochi kombu"), primarily for the Japanese market.

Red algae are also considered to have possible economic importance as food and in the production of the colloids carragenan and agar. The main markets for Porphyra spp., known as "nori" in Japan and "laver" in Europe are in Japan, China and Korea. U.S. imports of Japanese "nori" reached 15.5 million sheets worth U.S. $2.8 million in 1980 (Karmer, Chin and Mayo, 1982). Gracilaria and Gelidium species have been considered as possible sources of the colloid "agar" in B.C. Gymnogongrus leptophyllus, Neogardhiella baileyi and Iridaea spp. are potential carrageenophytes (plants from which the colloid carrageenan can be extracted). Chondrus crispus, the main species utilized in carrageenan production in eastern North America, is not native to B.C., but could probably be cultured here.

History

Early efforts to harvest seaweeds commercially off the B.C. coast in the 1940's were unsuccessful. In the late 1960's, there was a resurgence of interest in seaweed harvesting. A number of small companies were formed, some of which conducted seaweed inventories and applied for 20-year licenses over suitable areas. Most of these commercial efforts were unsuccessful. The strongest initiative was undertaken by the Canada Kelp Company beginning in 1967 when they applied for a license to harvest kelp (Macrocystis and Nereocystis) around the Queen Charlotte Islands. In the same year, they conducted a kelp inventory along the north coast of Graham Island. In 1968, they built a drying plant to produce kelp meal, and initiated construction of a 1,000 tonne-per-day harvesting vessel, which was incomplete when the company went into receivership. Its assets were subsequently purchased by another company, which carried out trial production of kelp meal in 1973. Production of kelp meal at the Masset facility on Graham Island has not been resumed since that time.

The Regional District of Skeena-Queen Charlotte commissioned a feasibility study for a kelp meal processing plant in 1978 with financial assistance from the B.C. Ministry of Industry and Small Business Development, and the federal Department of Regional Economic Expansion. The study, concluded in 1980, indicated that construction and operation of a kelp meal processing plant would not be commercially feasible at any of the Prince Rupert or Masset area sites, given the high capital costs, design criteria, and market takeover rate assumed by the consultants.

The most successful of the seaweed harvesting companies which emerged in the late 1960's were Sidney Seaweeds and the Pacific Kelp Company. The principal director of the latter company continues to harvest small amounts of seaweed for the production of plant care products.

While largely unsuccessful, these commercial harvesting ventures did stimulate the provincial Marine Resources Branch and the Industrial Development Division of the federal Fisheries and Marine Service to undertake kelp inventories and management research in the Graham Island area, and subsequently in a number of other areas, (Coon et. al. 1976; Field et. al. 1977; Field & Clark 1978;

Coon et. al. 1979; Coon and Roland 1980). This kelp management research program has continued for a number of years and is primarily focussed on Macrocystis and Nereocystis stocks in the Port Hardy area.

The Marine Resources Branch initiated studies in the mid-1970's to assess the biological and economic feasibility of harvesting wild Gracilaria spp. for agar production, and wild Iridaea spp. for carrageenans. These studies indicated that wild stocks of both of these species were not sufficiently abundant to sustain the development of a commercially viable industry, given extant prices for agars and carrageenans.

With respect to the production of other algal colloids, the Marine Resources Branch and the Department of Fisheries and Oceans jointly conducted a survey in 1977-78 of current and possible future markets for kelp meal, algin, agar and carrageenan. This study indicated positive results, with an estimated 2-5% annual growth in world markets for carrageenan, and a $350 per tonne premium for cultured products over the $750 per tonne base price. It was concluded that there was a market for B.C. carrageenophyte production. Kelp meal and algin market potentials were also concluded to be positive while that for agar, although fluctuating in response to wild stock yields, showed promise. On the basis of this positive outlook the Marine Resources Branch enhanced its funding of kelp management and culture technology development research.

No further research on the carrageenophyte Iridaea was undertaken as efficient production of high-quality carrageenan from Euchema spp. had been developed in the Phillipines. While the effect of this new source of carrageenan on existing producers in eastern Canada was minimal, it effectively eliminated the anticipated demand for new production from wild resources on the B.C. coast. The agar market being generally strong, it was decided to investigate the feasibility of Gracilaria culture, which had previously only been accomplished in Taiwan. Consideration of the industrial environment in Canada suggested the development of a capital-intensive algal culture system concept.

Seed stock screening of thirty species for colloid content, quality and culture suitability was undertaken, and indicated that Gracilaria spp. had the greatest potential for intensive culture for agar production, whereas Gymnogongrus leptophyllus and Neoagardhiella baileyi had potential for carrageenan.

Experimentation eventually led Canadian Benthic Ltd. to the design of an acceptable culture system based on modular floating bags with a surface area of 100 $m.^2$ (Saunders & Lindsay 1976; Lindsay & Saunders 1977, 1979).

The next phase of research was the development of system operating procedures to obtain maximum colloid production. However, during this phase of the program (1980), the agar market collapsed, due to the continued development of a highly-effective, labour-intensive carrageenophyte culture program in S.E. Asia, combined with market substitution of carrageenan for agar. As a result, the Gracilaria research program was suspended. It is of note, however, that the demand for high-quality agar and agarose for biomedical use remains very high.

Attention was directed to intensive, land-based tank culture of the carrageenophyte Chondrus crispus (Irish moss). In experimental trials, funded by the National Research Council and carried out at the Atlantic Regional Laboratory in Halifax, this species attained higher rates of growth under B.C. environmental conditions than with those prevailing in the Maritime provinces. However, culture production costs exceeded the costs of wild harvesting on the Canadian east coast (which are quite low) by $100 per tonne. Polyculture, in which a carrageenophyte could be produced with other plants or animals in an integrated culture system, has been suggested as one way of reducing the costs of carrageenophyte culture, but the suspension of the carrageenan research program precluded further research in this area.

In Washington State, the Lummi Indian tribe attempted to harvest the carrageenophyte Iridaea in 1969-70, but poor yields and high costs caused the operation to cease after one season. Subsequently, the Washington State Department of Natural Resources began to investigate methods for

culturing Iridaea. These studies led to the development of methods for seeding of nylon strings in tanks (Mumford 1977, 1978, 1979). The research program also provided information on preferable designs and operating guidelines for Iridaea culture and harvest systems.

Drs. R. Foreman (Bamfield Marine Station), R. DeWreede (University of British Columbia) and J. Whyte (Fisheries and Oceans) are currently (1982) in the third year of a proposed five year intensive research program on colloid-bearing red seaweeds in B.C. During the first phase of this research program, more than one hundred species of red algae were screened for colloid content, with interesting and important results. While a number of carrageenophytes were identified, and new types of carrageenan extracted, further research is being directed at agarophytes because of the strong market demand for high quality agar (e.g., $8,000/kg. retail for agarose, an agar-derivative). The most important result was the discovery of a new species of Gelidium which under natural conditions attains high biomass levels in winter. This new species is therefore well-suited to a stable, year-round production cycle with provision of cold, nutrient-rich waters by artificial upwelling during the summer.

The second phase of the research program is designed to develop cultivation techniques, and to produce sufficient material for the third phase of the program, which involves the pilot-scale extraction of high quality agar and subsequent trial marketing to determine potential price levels. Agar for this program should be available for test marketing in late 1983, and publication of the final report from this research program is expected in February, 1984.

With regard to edible seaweeds, Dr. Louis Druehl, a member of the faculty of Simon Fraser University, has undertaken edible kelp culture research, primarily in Barkley Sound, for four years. This research program is comprehensive, and indicates, among other things, that Laminaria groenlandica and Cymathere triplicata have the greatest potential as cultured "kombu" species under B.C. coastal environmental conditions. (Druehl 1980(a), 1980(b), 1981). Other components of the "kombu" research program include:

(1) characterization of species by weight, size, moisture, carbon and nitrogen content, and substantially, in order to identify those species which most closely approximate Japanese market requirements;

(2) culture of gametophytes and sporophytes for seed production;

(3) investigation of optimum methods and timing for outplanting of "seed";

(4) determination of site characteristics for optimum "kombu" production;

(5) determination of life histories and patterns of seasonal change of morphological features;

(6) research on drying characteristics;

(7) development of methods of cloning gametophytes in order to control genetic variability;

(8) determination of optimum harvesting strategies;

(9) design of culture systems and determination of operating procedures to obtain maximum growth and product quality.

In the most recent year of this research program, a number of small pilot "kombu" farms have been set up to assist in determining the economic feasibility of different scales of operation. In addition to Dr. Druehl and his associates, at least one other company is engaged in product development and promotion, with a view to introducing 'kombu' products to the North American market.

Similar research and development work has been undertaken by the Washington State Department of Natural Resources on the culture of Porphyra spp. in Puget Sound. Culture systems for Porphyra are very well-developed in Japan, where there is a large market for "nori" -- 8.3 billion sheets valued at over U.S. 500 million per year in 1980. The Washington

researchers are trying to adapt Japanese culture technology for use with native species of Porphyra. The Department of Natural Resources is also conducting research to determine the ideal oceanographic conditions for culturing "hori" in Puget Sound, and to select the most suitable native Porphyra species for culture. It is important to point out that this research program is aimed at producing "hori" for the American market, as Japanese production continues to exceed demand in the large Japanese market.

Licensing and Jurisdictional

Because the culture of seaweeds is a new concept in British Columbia and Canada, there is little existing legislation and no regulations relating specifically to the culture of marine plants. The proposed provincial Marine Resources Act will include provisions allowing regulation of the marine plants industry, and these provisions would be similar in many ways to the regulations governing shellfish culture, for example:

(1) regulation of transportation and transplantation of seed stock (to protect against the transmission of diseases and predators);
(2) registration of growers, with a reporting requirement;
(3) reservation of critical areas for protection as sources of seed, or recreational harvesting reserves (as Pendrell Sound and Pipestem Inlet are currently reserved for the production of oyster seed).

With the development of the seaweed industry, the Marine Resources Branch will also hope to provide a number of services to the industry, in order to promote the development of the industry, and to safeguard areas with a high production potential. The types of services which might be provided would be similar to those provided to the shellfish mariculture industry, and are as follows:

(1) habitat protection;
(2) lease assessment to advise regarding the suitability of prospective leases and to set lease rental fees;
(3) provision of biological and technical advice to prospective and existing growers;
(4) referral agency for outside institutions (i.e., banks regarding economic and financial viability: Agricultural Credit Act);
(5) co-ordination of the acquisition of tax-free status for certain types of culture equipment;
(6) possible marketing promotion assistance on an industry-wide basis.

Seaweed growers do not need a federal mariculture license, so the regulatory role of the federal Department of Fisheries and Oceans is restricted to commenting on lease applications referred to them by the provincial Ministry of Lands, Parks and Housing. Lease applications for seaweed culture are handled by the provincial government in the same way as lease applications for oyster culture. In this regard, the usual referral of applications to the Department of Transport for approval under the Navigable Waters Protection Act may be a particular problem for seaweed farmers due to the nature of the culture system.

Biological and Technical Research

Dr. Mumford of the Department of Natural Resources in Washington is currently undertaking research in Puget Sound on the requisite environmental conditions for "nori" culture, the most suitable species of Porphyra for culture, the effects of diseases and pollution on "nori" culture, and on adapting Japanese harvesting and processing techniques. Further research is required on seeding technology and herbivory and disease control.

The comprehensive research program on "kombu" culture is substantially complete. Work is being undertaken currently to identify optimum environmental conditions for "kombu" culture. Further research is needed in the following areas:

(1) seed production techniques for Cymathere triplicata;
(2) suitability of Laminaria groenlandica for roe-on-kelp and selection of the most suitable strains for roe adhesion;
(3) selection of optimum strains for edible kelp markets and efficient production;
(4) analysis and control of effects of disease and herbivory;
(5) experimental processing and marketing, and review of Japanese processing methods.

Dr. Foreman of the Bamfield Marine Station is undertaking research to develop techniques for culturing the "winter growing" Gelidium sp. which was discovered during the red algal colloid research program undertaken by Drs. Foreman, DeWreede and Whyte.

Should results from the test marketing of Gelidium-derived agar be encouraging, considerable further research will be required to develop efficient culture and harvesting systems.

Should the market for carrageenan improve, research could be conducted on harvesting strategies, techniques for fertilization and effects of fertilization, and harvesting machine design for Iridaea culture. Consideration could also be given to a commercial pilot scale operation of the land-based culture system developed for Chondrus culture by Genu Products Ltd., and/or Marine Colloids Ltd. Depending on the demand for special colloids, further production studies might be undertaken on Gymnogongrus leptophyllus and Neoagardhiella baileyi.

Market and Economic Research

A number of marine plant research programs currently in progress have marketing and/or economic research components. The "nori" research program being undertaken in Washington State included a

survey of North American retailers, restaurants and health food outlets with regard to the existing market for "nori" and potential future market growth. (Kramer, Chin & Mayo 1982). The preliminary economic analysis undertaken as part of the research program indicates that the total costs per "nori" sheet decline rapidly from 100-to-300 net farms. The cost suggests that a 300-net farm will realize most of the available economies of scale and will be competitive with a larger corporate farm (2,000 nets) as far as production costs are concerned.

The 300-net farm is projected to show positive net present values at the most conservative level of project life (15 years) and real discount rate (15%) and even at product prices 20% below those used in the pro forma calculations ($ 0.055/sheet).

Dr. Druehl has been undertaking research on the comparative economic advantages of various scales of "kombu" production. This research has been undertaken in conjunction with studies to determine the suitability of the proposed culture system in various oceanic environments as well as the most favourable environmental conditions for "kombu" culture.

Following completion of the second phase of their B.C. Science Council funded red algal colloids research program, Drs. Foreman, DeWreede and Whyte propose to produce enough of the new species of Gelidium to test and develop a pilot-scale agar-extraction plant, and to test the market for high-quality agar through the sale of a commercial quantity of the agar extracted.

Little further research is required at the present time on markets for phycocolloids. It is apparent that, with the exception of technical grade agar, current world production of algal colloids (agar, algins, carrageenans) may be closely matched to, or exceed, total demand, at least for some of these colloids. However, international markets and production trends should

be monitored to identify potential long-term windows for B.C. produced phycocolloids. The bright market prospects for technical grade agar and agar-derivatives suggest that the test-marketing of high-quality agar from Gelidium, which is proposed by Drs. Foreman, DeWreede and Whyte, should be followed by a detailed economic analysis of production and extraction costs relative to potential prices, if the results of the test-marketing are encouraging.

The main markets for edible "nori" and "kombu" are in Japan but these are extremely difficult to break into because of protectionist trade policies and highly efficient and massive seaweed production in Japan and China. While markets of unknown size exist in Taiwan and South America, initial development of the edible seaweed industry in B.C. will probably be dependent on the exploitation of existing North American markets (primarily in Oriental communities) and the development of new home markets. The U.S. currently imports about $5.5 million per year of seaweed products; one-half of this is supplied by imports from Japan. Product development and market research and promotion are key requirements for development of a local edible seaweed industry. In this respect, there may be lessons to be learned from the market development approaches used for other products which were initially as "strange" as seaweeds are now -- for example, tofu and yogurt. It is important to note that the primary use for "kombu" in Japan is in soups, and for "nori" as a condiment, so markets for these products may never be large enough to sustain more than a few moderate-sized farms.

Market development and research for "kombu" will not obviate the need for further economic analysis of "kombu" culture. Detailed economic evaluation of "kombu" culture, using either a "model" farm (similar to the model developed for salmon farming by Jim Fralick) using information from Dr. Druehl's research, or, preferably, a commercial trial "kombu" farm should be a high priority research item. While a lot of information

has been developed on seed production and culture technology, a detailed economic evaluation of "kombu" production will also require considerable research and/or experimentation on processing (drying and curing techniques) and processing, marketing and distribution costs.

Another possible use for cultured Laminaria kelp which has been suggested is for roe-on-kelp ("komochi kombu"). Laminaria was used in the initial stages of development of the roe-on-kelp industry, particularly in areas like the Strait of Georgia where Macrocystis is not found. It continues to be used in Alaska for roe-on-kelp operations. With the "kombu" culture techniques developed by Dr. Druehl, it is possible to produce very uniform kelp. However, there are several difficulties with using cultured Laminaria for roe-on-kelp production -- the first is that the Japanese have developed a strong preference for Macrocystis based "komochi kombu".

A second possible constraint to roe-on-Laminaria production is the very high level of low-cost, cultured Laminaria production in China in areas where herring spawning also occurs, such that if a market for roe-on-Laminaria could be developed, the Chinese would have a strong competitive advantage in that market. Nonetheless, there are sufficient unknowns regarding the marketability of roe-on-Laminaria that test marketing of the production of a small, pilot roe-on-cultured Laminaria operation may be worthwhile.

The Gas Research Institute in California is undertaking research to produce methane, alcohol, algin, and other products from Macrocystis pyrifera grown in oceanic farms, each covering up to 100 sq. miles in area. Funding for this work has recently been severely curtailed due to an unfavourable economic outlook: however, the small research program which is continuing should be monitored for technological advances which would result in significant reductions in production costs.

Summary

The economic potential of marine plant culture in B.C. is uncertain at the present time. As a result of current research, prospects are brightest for the cultivation of a winter-growing Gelidium species on a year-round production cycle (with artificially-upwelled, cold and nutrient-rich water in the summer) to produce high quality agar and derivatives for the biomedical market. Demand in this market is strong, with retail prices of $8,000/kg. for agar derivates. Carrageenophyte production will probably not be commercially viable for the foreseeable future due to increasing production in a number of countries with competitive advantages in terms of labour costs and environmental conditions. The same argument can be made with respect to the production of agarophytes for the food grade agar market. The prospects for commercially-viable production of edible seaweeds are somewhat better, with "nori"-culture having perhaps the greatest known potential, due to the market and economic analysis undertaken by the Washington State Department of Natural Resources. A pilot "nori" farm in Canada might be a useful way of further elucidating the economic potential of Porphyra culture. A rigorous economic analysis of "kombu" culture, based on the bio-technical research of Dr. Druehl, may indicate a similar economic potential for the farming of Laminaria groenlandica. Certainly, in both cases, product development and development of North American markets for "hori" and "kombu" are of crucial importance to the development of the edible seaweed industry, as far eastern markets are currently well-supplied.

It is important to point out that for any species or end uses which might prove economically feasible, potential market sizes will probably be sufficient to support only a few moderate-sized production units.

Current indications regarding the economic potential of marine plant culture for other end products, like large scale production of methane gas for energy or pharmaceutical production, are not encouraging. Research in these areas should be monitored for possible economically significant developments.

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SHRIMP, PRAWNS, LOBSTER and CRAB

SHRIMP/PRAWNS, LOBSTER, CRAB

SHRIMP AND PRAWN CULTURE

Introduction

Prawns and shrimp are fished on the British Columbia coast. No attempt has been made to culture either in B.C., although some rearing work has been carried out by researchers.

Biological/Technological/Economic Issues

Culture of shrimp and prawns in British Columbia could be envisioned for local pandalids, probably the spot prawn, in either monoculture or polyculture systems, for example, with abalone or with salmon in pens (cf Neilson 1981). However, growth rates in British columbia may be too low for commercial viability of monoculture (alluded to in Neilson 1981, and in Marliave pers. comm.; and concluded for elsewhere as well in Kelly et al 1977).

Polyculture possibilities may be somewhat better, since prawns could act as cleaners and scavengers as well as provide additional income in such systems; however, this is not possible without further work on a variety of biological, technological and economic problems. Examples include prawn cannibalism, which limits stocking densities in pens (Marliave pers. comm.), and temperature and salinity lethal limits of spot prawns in B.C. (Kelly et al 1977). Marliave (pers. comm.) indicates that the published report of unsuccessful spot prawn polyculture (Rensel and Prentice 1979) involved unacceptable salmon farming procedures, such as leaving the nets fouled and not removing dead fish. Thus, considerable work in a number of areas is needed before prawn monoculture or polyculture could be considered feasible.

Conclusions and Recommendations

Despite abundant literature and commercial success of shrimp and prawn culture elsewhere, it can be generally concluded that shrimp and prawn

culture in B.C. offers very little potential, in the short to medium term, since there seem to be major problems in growth rates, technology availability and economics of production.

While prawn and shrimp are of low priority at this time, a more thorough evaluation of the data presented by Neilson and others is probably warranted.

LOBSTER

Introduction

The American lobster (Homarus americanus) is not native to British Columbia. "At least ten major transplant attempts over a 75 year period" were carried out by Department of Fisheries and Oceans using lobsters from the Atlantic coast (cf Carefoot 1977), but none of these were successful.

History

Two kinds of lobsters may be considered for mariculture: the clawed lobster (Homarus americanus in North America) and the clawless or spiny lobsters. Although some experimental culture work on spiny lobsters has been done in the U.S., Japan, and Australia (Bardach et al 1972, Cobb and Phillips 1980), culture technology for these species is not sufficiently developed to be encouraging for aquaculture in the near future. Culture work on clawed lobsters is much more advanced.

The methodology of culture and holding in captivity seems to be well established on the east coast. In addition, a considerable amount of work has been done at the University of California, Bodega Bay site. While this is not intended as a commercial operation, the cost of production of $44 per kg., according to one account, seems high. Considerable work has been done on feed, genetics and engineering culture systems.

The optimum biological conditions for growth are:

- temperature between 15 and 20 degrees Celsius (growth stops at 4 degrees or lower)
- salinity above 22 parts. (Jamieson pers. comm.).

Extensive hatchery work has been carried out on the east coast. Knowledge of gaffkemyia, and the methods for preventing its spread (a vaccine is close to production as well), is growing. While fish waste (e.g. cod heads) will keep lobster alive, krill and red crab is needed to balance the diet. Lobster culture might well concentrate on producing a "scampi" sized animal of about 250 g. at less than 2 years of age, compared with a full-sized lobster at 4 or 5 years.

Lobster ponds in eastern Canada have had some success in growing small commercial sized animals for May/June through to December, with a doubling in size. One molt results in approximately a 25% increase in weight.

Broodstock is probably available and could be brought into B.C. It would be important to obtain approximate information on costs of production and selling price, as well as on demand and markets, to evaluate potential of lobster culture. Workshop participants expressed doubts as to the willingness of the Federal government to support a large scale development of lobster culture on the west coast for both political and biological reasons. In other words, it is presumed that the east coast fishery would have the first claim on any publicly funded culture or enhancement program.

Conclusions and Recommendations

1. The spiny lobster has little potential for culture at this time.

2. The clawed lobster has potential for culture in B.C., provided that solutions can be found to the following problems:

   - cost of augmenting water temperature
   - diet cost
   - the possibility of gaffkemyia infections
   - changes in salinity in open water systems.

3. Questions remain as to the political ramifications of attempting lobster culture in B.C.

CRAB

A short discussion was held during the workshop on the mariculture potential of crabs. No attempts have been made to culture either Dungeness (Cancer magister) or Graceful (Cancer gracilis) crab in B.C. T. Butler mentioned attempts made in Humboldt Bay to hold sublegals for the time required for a final molt, after which they attain legal size. They were fed scrap fish; subsequently, they stopped eating but resumed eating and gained weight when shrimp waste was added to their diet. Costs of feed may be too high to be supported by the present selling price of $1.40 per lb. for Dungeness crab, which was reported at the workshops. These cost relationships, as well as demand and markets, should be investigated on the basis of existing information for a further evaluation of potential.

The Graceful crab may be culturable but there is no data on growth rates; females in nature reach maturity (3-4 inches) in about three years (Butler).

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GOOSENECK BARNACLES

GOOSENECK BARNACLES

Introduction

Two species of gooseneck barnacle are present in the waters of British Columbia. The well known variety, Pollicipes polymerus, is found on exposed rocks on the outer coast. It was traditionally used by Indians and has been subsequently harvested in response to market enquiries from Spain. In 1978/79, testing of this market indicated a potential market of between $3 - $5 million (Proverbs 1979), a figure which was estimated by exporters. This species is very slow growing and does not appear to be a candidate for mariculture (Goldberg pers. comm.).

The other species, Lepas anatifera (Linnaeus), "is normally found attached to floating objects such as buoys, boats and driftwood. It has a cosmopolitan distribution" (George 1979). The extremely rapid growth of Lepas makes it a possible mariculture species for British Columbia, although much research and development remains to be done.

History

The most extensive effort to collect and culture Lepas was carried out by H. Goldberg in 1980. This research showed that seed is obtainable, with difficulty, at sites beyond the Continental Shelf, off the west coast of Vancouver Island. This seed was then transferred to a grow-out site at Bamfield where stalk growth of up to 10 cm between May and October was observed (Goldberg pers. comm.). Grow-out took place from long lines associated with a mussel culture operation. The Bamfield area does not experience surface water temperatures much higher than 20°C and salinities are generally high.

Economics/Financial Requirements

Nothing is known of the economics of goose barnacle culture, although the solutions to the problems detailed below will strongly influence the economics of culture.

Biological and Technical Requirements

For Lepas to be profitably cultured, a hatchery seed source is required. As well, additional basic biological research is needed to establish culture parameters, temperature, salinity, ability to withstand competition, etc.

Market and Marketing Research

It is known that Pollicipes polymerus from wild harvest was well accepted in Spain. When Pollicipes polymerus was sold in Spain it was sent by air, fresh. It is not known at this time how acceptable the thinner stalk of Lepas will prove to be in this market. Samples of Lepas have been sent to Spain to assess marketability. Presumably Lepas would be shipped still attached to the cultch. It is not known to what extent this product could sell locally. The stalk is the part which is eaten, after the outer, leather-like, skin is removed.

Conclusions and Recommendations

Lepas, due to its extraordinary growth rates by mariculture standards, should continue to receive research attention. Such research should be concentrated in the areas of seed procurement and grow-out systems, provided the sample products sent to Spain prove acceptable to that market.

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